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THE COMPOSITION AND CLASSIFICATION OF FOREST FLOORS AND RELATED SOIL PROFILES IN SASKATCHEWAN[1]

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A study of the forest floor is a branch of soil science which has received very little attention. Pedologists in proposing new systems of soil classification generally have been reluctant to deal with the forest humus layers. Joffe (6), as well as other workers, has pointed out the importance of the organic layers in the process of podzolization. It would therefore seem that the humus layers should be considered as part of the soil itself.

The term "forest floor" is defined as the accumulation of organic matter on the soil surface under forest cover (8). In terms of soil horizon designations this includes the A_{00} horizon which is referred to as the leaf litter layer (LL), and the A_0 horizon which may be further subdivided into the "fermentation" (F) and "humified" (H) layers. The F layer consists of the more or less decomposed forest litter, still recognizable as to origin. The H layer consists principally of organic matter, usually unrecognizable as to origin (5). Either F or H layers may be absent in some forest soils.

One important development in the field of forest floor studies has been the establishment of a system of nomenclature for the different types of forest floors occurring in northeastern United States (5). The above mentioned paper gives a complete review of former methods of nomenclature and directs attention to the variations in morphological features of the A_0 horizon which can easily be recognized in the field. The material presented in the above mentioned paper served as a guide in the classification of Saskatchewan forest floors.

Location and Extent

The forests of Saskatchewan, which have been classified by Halliday (4) as belonging to the boreal forest region, occupy about 100 million acres of the province (9) and of this acreage about 6.5 million acres are in forest reserves (12). The denser forests occur in the "gray" and "gray-black" transition soil zones of Saskatchewan which occupy about 31 million acres (9). (Figure 1.)

Vegetation

In the forest region of Saskatchewan the characteristic association is a mixture of aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*) white spruce (*Picea glauca*), and white birch (*Betula papyrifera*). Jack

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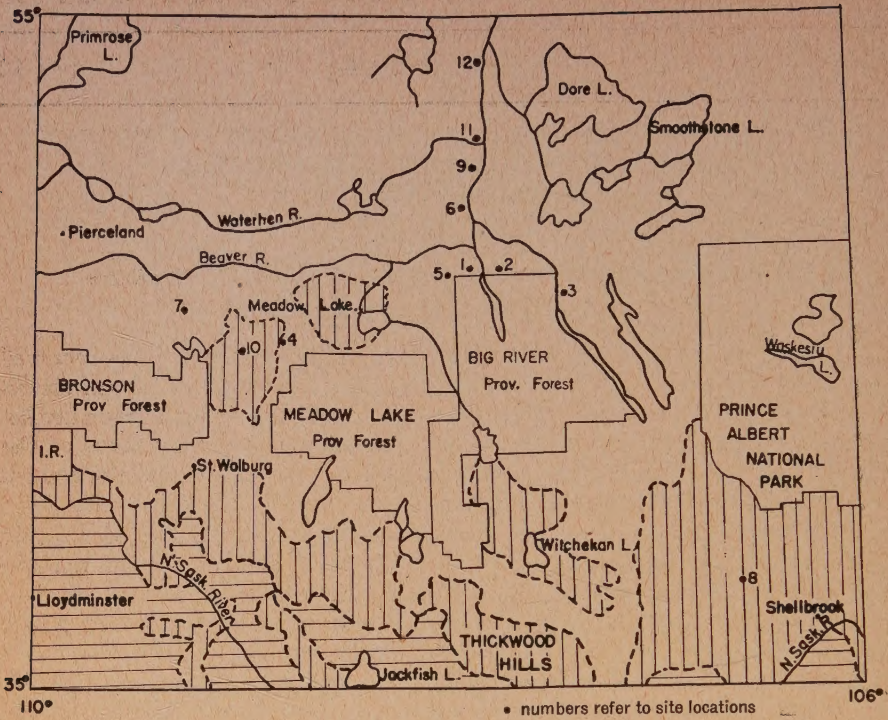
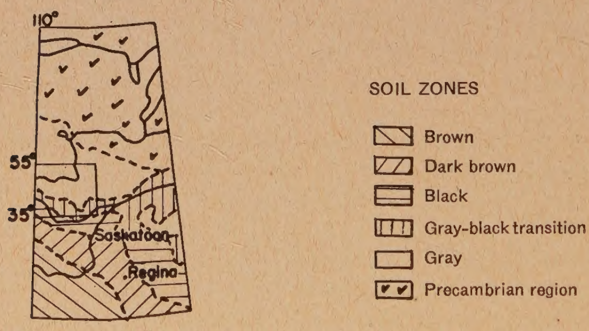


FIGURE 1. Sectional map showing soil zones and sample sites. •

Additional data



pine (*Pinus banksiana*) associations tend to predominate on the coarse textured gravelly sandy areas. The depressional areas develop black spruce (*Picea glauca*) and tamarack-sphagnum bogs which are not, however, of any great depth. Willows (*Salix sp.*) occur on alluvial deposits along streams and rivers.

Climate

The climate of the area concerned is classed as cool temperate with most of the precipitation falling during the short growing season. Meteorological data (10) indicate that the precipitation is less than 20 in. annually with most of it coming in the 5 summer months, May to September. Mean

monthly temperatures vary from about −10° F. in January to 60° F. in July. Winter temperatures lower than −65° F. and summer temperatures above 100° F. have been recorded.

SAMPLE SITES AND PROFILE DESCRIPTIONS

All of the sample sites were selected to represent, as nearly as possible, undisturbed old forest floors. The profile descriptions are given below and location of the sites is given in Figure 1.

SITE 1

Date of sampling:—August 7, 1944.
Forest floor type:—Granular mor.
Profile type:— Podzol.
Vegetation:— White spruce *Picea glauca* up to 18 in. d.b.h.,[1] twin flower Mitrewort, etc.
Topography:— Undulating.
Parent material:— Lacustrine.

A_{00}		Not sampled.
A_0	0 to 4 in.	H layer—Dusky reddish brown, somewhat matted fairly well decomposed organic material with pieces of roots easily discernable.
A_1	4 to 5 in.	Brownish gray mixture of mineral soil and well decomposed organic matter.
A_2	5 to 14 in.	Light brownish grey very fine sandy loam, platy structure crushing easily into powder.
B_1	14 to 18 in.	Rusty pale brown clay high in very fine sand, nutty structure breaking into coarse granules.
B_2	18 in. +	Brownish gray heavy clay, tough fragmental structure.

SITE 2

Date of sampling:—October 15, 1944.
Forest floor type:—Granular mor.
Profile type:— Rendzina-like.
Vegetation:— White spruce *Picea glauca* up to 24 in. d.b.h. sphagnum moss, Labrador tea, etc.
Topography:— Undulating.
Parent material:— Highly resorted boulder clay.

A_{00}	0 to $\frac{1}{4}$ in.	LL layer. Undecomposed needles, cones, and twigs.
A_0	$\frac{1}{4}$ to 5 in.	H layer. Pale brown granular slightly matted, fairly well decomposed organic material.
A_1	5 to 7 in.	Weak brown fine granular mixture of mineral soil and well decomposed organic matter. Slightly limy.
A_2	7 to 8 in.	Brownish gray moderately limy clay loam; cloddy nutty structure easily crushed to powder.
A_3	8 to 11 in.	Very light yellowish brown rust specked silty clay loam; moderately limy; platy structure easily crushed to powder.
B_1	11 to 24 in.	Light yellowish brown silty clay, flat topped columnar structure breaking into soft granules, faint laminated tendency.

[1] d.b.h.—diameter at breast height.

SITE 3

Date of sampling:—October 15, 1944.
Forest floor type:—Granular mor.
Profile type:— Podzol.
Vegetation:— White spruce *Picea glauca* up to 12 in. d.b.h. mixed with dead poplar (Populus sp.) up to 24 in. d.b.h., sphagnum, bunch berry, etc.
Topography:— Undulating.
Parent material:— Heavy lacustrine.

A_{00}	0 to $\frac{1}{4}$ in.	LL layer. Broken cones, needles, and twigs.
A_0	$\frac{1}{4}$ to 3 in.	H layer. Dark brown granular fairly well decomposed organic material held together by considerable gray mold.
A_1	3 to $3\frac{1}{2}$ in.	Dusky brown granular mixture of mineral soil and well decomposed organic matter.
A_2	$3\frac{1}{4}$ to 10 in.	Light gray silty clay loam, with platy structure which crushes easily to fine granules and powder.
B_1	10 to 24 in.	Light brownish gray heavy clay, very tough nutty structure.
B_2	24 to 36 in.	Heavy clay, pale brown in colour, mottled with gray, extremely tough fragmental structure.

SITE 4

Date of sampling:—September 23, 1944.
Forest floor type:—Matted mor.
Profile type:— Podzol.
Vegetation:— Aspen *Populus tremuloides* up to 10 in. d.b.h., prairie rose, pea vine, grass, etc.
Topography:— Undulating.
Parent material:— Boulder clay.

A_{00}		Too thin to sample.
A_0	0 to $\frac{1}{4}$ in.	F layer. Dark brown slightly decomposed leaf litter and twigs.
	$\frac{1}{4}$ to $2\frac{1}{2}$ in.	H layer. Brownish black matted organic material fairly well decomposed.
A_1	$2\frac{1}{4}$ to 4 in.	Dusky brown granular mixture of mineral soil and well decomposed organic matter.
A_2	4 to 8 in.	Light brownish gray loam, thick platy structure breaking to small nutty platy fragments.
B_1	8 to 16 in.	Light brownish gray clay, tough fragmental structure.

SITE 5

Date of sampling:—October 14, 1944.
Forest floor type:—Matted mor.
Profile type:— Podzol.
Vegetation:— Aspen *Populus tremuloides* up to 18 in. d.b.h., pea vine, prairie rose, golden rods, twin flower, strawberry, grass, etc.
Topography:— Very gently rolling.

Parent material:— Lacustrine.

A_{00}		LL layer. Undecomposed leaves and twigs.
A_0	0 to $\frac{1}{4}$ in.	F layer. Brownish black slightly decomposed leaves and twigs.
	$\frac{1}{4}$ to 2 in.	H layer. Dusky brown matted fairly well decomposed organic material.
A_2	2 to 8 in.	Very pale brown clay, platy to hard granular structure.
B_1	8 to 14 in.	Pale brown heavy clay, fairly tough fragmental to coarse granular structure.
B_2	14 to 22 in.	Yellowish light brown silty clay, fragmental structure.

SITE 6

Date of sampling:—October 14, 1944.
Forest floor type:—Matted mor.
Profile type:— Podzol.
Vegetation:— Paper birch *Betula papyrifera* up to 12 in. d.b.h. with occasional small alder (*Alnus incana*), marsh reed grass, twinflower, Labrador tea, blueberry, reindeer moss, etc.
Topography:— Undulating.
Parent material:— Lacustrine.

A_{00}		Too thin to sample.
A_0	0 to $\frac{1}{4}$ in.	F layer. Slightly decomposed leaves, twigs and grass.
	$\frac{1}{4}$ to $1\frac{1}{2}$ in.	H layer. Weak brown, very matted fairly well decomposed organic material.
A_1	$1\frac{1}{2}$ to $1\frac{3}{4}$ in.	Dusky brown mixture of mineral soil and well decomposed organic matter with quite a few rootlets.
A_2	$1\frac{3}{4}$ to 5 in.	Very pale brownish gray very fine sand, coarse granular structure crushing easily to fine powder.
B_1	5 to 15 in.	Light yellowish brown loamy very fine sand, soft cloddy structure crushing easily to powder.

SITE 7

Date of sampling:—October 14, 1944.
Forest floor type:—Matted mor.
Profile type:— Podzol.
Vegetation:— Balsam poplar *Populus tacamahacca* up to 24 in. d.b.h., prairie rose, snowberry, bunchberry, twinflower, etc.
Topography:— Undulating.
Parent material:— Alluvial.

A_{00}		LL layer. Undecomposed leaves and twigs.
A_0	0 to 4 in.	H layer. Dark brown matted well decomposed organic material.
A_2	4 to 24 in.	Very pale brown loamy very fine sand, faint platy structure crushing easily into fine granules and powder.
B_1	24 in. +	Light yellowish brown rusty very fine sandy loam faint cloddy structure crushing easily into medium granules.

SITE 8

Date of sampling:—October 16, 1944.
Forest floor type:—Dry mor.
Profile type:— Podzolized sand.
Vegetation:— Jack pine *Pinus Banksiana* up to 12 in. d.b.h., bear berry, moss cranberry, etc.
Topography:— Very gently rolling.
Parent material: Alluvial sand.

A_{00}		LL layer. Undecomposed needles, cones, and bark.
A_0	0 to ¼ in.	H layer. Weak brown well decomposed needles mixed with some grains of sand.
A_2	¼ to 1 in.	Brownish gray medium sand held together by small root hairs.
B	1 to 2½ in.	Light yellowish brown sand, soft cloddy structure.
C	2½ in. +	Strong yellowish brown structureless sand.

SITE 9

Date of sampling:—September 9, 1944.
Forest floor type:—Dry mor.
Profile type:— Podzolized sand.
Vegetation:— Jack pine *Pinus Banksiana* up to 12 in. d.b.h., club moss, bearberry, moss cranberry, Laborador tea, etc.
Topography:— Very gently rolling.
Parent material:— Alluvial sand.

A_{00}		LL layer. Undecomposed needles, cones, and bark.
A_1	0 to ¼ in.	Well decomposed organic matter mixed with brownish gray structureless sand.
A_2	¼ to 2½ in.	Brownish gray fine sand held together with fine rootlets
B	2½ to 5 in.	Light yellowish brown fine sand, very faint cloddy structure.
C	5 in. +	Light yellowish brown structureless sand.

SITE 10

Date of sampling:—October 13, 1944.
Profile type:— Shallow peat on calcareous soil.
Vegetation:— Black spruce *Picea mariana* up to 15 in. d.b.h., Laborador tea, twinflower, Mitrewort, etc.
Topography:— Depressional.
Parent material:— Lacustrine

A_{00}		Undecomposed twigs, cones, and needles.
A_0	0 to ¾ in.	Layer 1. Slightly decomposed needles, dusky brown in colour.
	¾ to 5½ in.	Layer 2. Weak brown granular loosely matted fairly well decomposed organic material.
A	5½ to 12 in.	Black mineral soil very high in well decomposed organic matter, fine granular. Remains of charred wood present.
B	12 to 16 in.	Dusky brown clay, soft cloddy structure breaking down to fine granules.
C	16 to 24 in.	Light yellowish brown clay quite limy.

SITE 11

Date of sampling:—October 15, 1944.
Profile type:— Shallow peat on calcareous soil.
Vegetation:— Willow *Salix* sp., up to 9 in. d.b.h., nettles, ferns, raspberries, etc.
Topography:— Level.
Parent material:— Recent alluvial

A_0	0 to ¼ in.	Layer 1. Very slightly decomposed leaves.
	¼ to 3 in.	Layer 2. Dark brown quite loose well decomposed organic matter.
A	3 to 13 in.	Dusky brown mixture of mineral soil and very well decomposed organic matter. Cloddy structure crushing easily to fine granular structure.
G	13 to 25 in.	Rusty brownish gray silt loam, soft cloddy structure.
C	25 to 36 in.	Pale brown rust streaked silty clay.

SITE 12

Date of sampling:—October 15, 1944.
Profile type:— Sphagnum peat.
Vegetation:— Tamarack *Larix laricina* up to 6 in. d.b.h., sphagnum, Laborador tea, blueberry, etc.
Topography:— Depressional.

A_{00}		Undecomposed needles.
A_0	0 to 4 in.	Layer 1. Light olive brown raw sphagnum and some partially decomposed needles.
	4 to 8 in.	Layer 2. Light yellowish brown slightly decomposed sphagnum moss, very loose and spongy.
	8 to 10 in.	Layer 3. Weak brown well decomposed organic material permeated with rootlets and fairly compact.
C	10 to 30 in.	Very pale brown structureless sand.

DISCUSSION OF FOREST FLOORS

The forest floors of Saskatchewan belong to the mor group. This group is characterized by a layer of unincorporated organic material usually matted or compact or both, distinctly separable from the underlying mineral soil unless the latter has been blackened by washing in of organic matter. Three main types have been recognized in this group, namely, granular, matted, and dry mor.

The granular mor type occurs mainly under solid stands of white spruce. It is recognized by the absence of a well developed root mat in the H layer. A generalized description of this type is given below:—

(1) LL layer. Undecomposed needles, cones, and twigs. Very seldom exceeds ¼ in. in thickness.

(2) F layer. Usually absent.

(3) H layer. Granular, slightly matted, well decomposed organic matter. Varying shades of brown in colour. Has been found up to 5 in. in thickness but is more often around 3 in. thick under fairly heavy tree cover.

The matted mor type is found under the deciduous trees—aspen, balsam poplar, and birch. This type is characterized by a dense root mat holding the H lay together and is described as follows:—

(1) LL layer. A thin layer of undecomposed leaves and twigs.

(2) F layer. Slightly decomposed leaves and twigs with no evidence of matted or laminated structure. Usually dark brown in colour. This layer is quite thin, usually about $\frac{1}{4}$ in. thick, and may be absent.

(3) H layer. Fairly well decomposed organic matter. It is held together by a network of fine roots. This layer is usually thinner than the H layer of granular mor, and very seldom exceeds 3 in. in thickness.

The matted mor type may also be found under mixed aspen and white spruce forest cover, but here we find graduations in type from matted to granular mor depending on the relative numbers of each tree variety present.

The dry mor type is found under jack pine. Solid stands of jack pine in Saskatchewan occur principally on well drained sandy and gravelly soils which are very low in fertility. The combination of low fertility and excessive drainage seem to result in the development of a very thin forest floor, which is chiefly composed of litter consisting of undecomposed needles, cones, and bark. No F layer is present and the H layer is a very thin mat of well decomposed loose, structureless organic matter, quite often mixed with fine grains of sand. The classification of humus layers in northeastern United States made no provision for a forest floor of this type which belongs to the mor group. The name "dry" mor is suggested for this type of forest floor because of its very poor development; it appears rather dry and arid in comparison with other humus types encountered.

The combination of a short growing season and low annual rainfall prevailing in Saskatchewan forest areas results in a less dense tree cover, smaller leaves, and lighter leaf fall than is found in areas such as northeastern United States. This climatic factor is reflected in the development of thin humus layers, and in many instances no F layer is discernable.

Local variations in thickness of the forest floor depend on the nature of the mineral part of the soil—its texture, structure, drainage, and chemical composition, and on topography. Thinner organic layers are expected where the soil is lighter in texture, excessively drained, and lower in plant nutrients; they would also be expected on the crest of a hill.

The classification of forest floors as proposed by Heiberg and Chandler (5) was applied only to well-drained upland soils. However, it has been noticed that the organic layers developed under white spruce on a rendzina-like soil are quite similar in morphological features to those layers developed under white spruce on podzol soils. Further, chemical data presented in this paper will also show considerable similarity between the forest floors developed on a podzol and a rendzina-like soil type.

The humus layers under black spruce and willow cannot be classified with upland types, because these trees are confined primarily to swamps and poorly drained locations. It is interesting to note that we have an A_0 horizon under black spruce which consists of two layers—the upper layer is thin and slightly decomposed while the lower layer is thick, granular and

well decomposed being quite similar to the H layer under white spruce. These layers have been numbered for convenience in referring to the A_0 horizon. Two well developed humus layers were separated under willow. Layer 1 was quite thin and closely resembles the F layer of upland humus types while layer 2 had no noticeable structure, being quite loose and open.

In conducting this study, chemical analysis of forest floors, and peats and their related soil profiles have been carried out to determine whether or not:—

(i) similar forest floor types are similar in chemical composition;

(ii) differences in morphological features of forest floor types are reflected by differences in chemical composition;

(iii) the organic constituents of leaf litter from various tree species undergo somewhat similar changes during decomposition; and

(iv) to present data on chemical composition of forest and sphagnum peats in Saskatchewan.

ANALYTICAL DATA AND DISCUSSION

Methods

The pH was determined with a Coleman pH electrometer. Total nitrogen and loss-on-ignition were determined by standard analytical procedures, while the dry combustion method was used to determine total carbon. Procedures for proximate analysis, as outlined by Waksman and Stevens (13, 14) were used to determine organic constituents. The method proposed by Blish and Sandstedt (2) was adopted for determining percentage of hemicellulose and cellulose.

Table 1 gives the pH, loss-on-ignition, nitrogen, organic carbon, and C/N ratios for the forest humus layers and peats and their related soil profiles.

TABLE 1.—ANALYTICAL DATA FOR PROFILES ON SITES NO. 1 TO NO. 12. RESULTS EXPRESSED ON OVEN DRY BASIS

Horizon or layer	Depth	pH	Loss-on-ignition	Nitrogen	Carbon	C/N
			%	%	%	
Site 1. Granular mor. White spruce on podzol.						
H	0 to 4 in.	5.73	90.86	2.03	49.60	24
A_1	4 to 5 in.	5.10	9.29	0.198	4.14	21
A_2	5 to 14 in.	5.30	1.50	0.066	0.35	5
B_1	14 to 18 in.	5.10	2.45	0.011	0.44	40
B_2	18 in. +	6.12	3.90	0.031	0.56	18
Site 2. Granular mor. White spruce on rendzina-like soil profile.						
LL	0 to ¼ in.	5.60	90.64	1.17	47.60	41
H	¼ to 5 in.	5.05	90.24	1.53	50.70	33
A_1	5 to 7 in.	7.80	39.99	1.02	22.37	22
A_2	7 to 8 in.	8.00	13.01	0.41	7.42	18
A_3	8 to 11 in.	8.10	1.32	0.018	0.43	24
B_1	11 to 24 in.	7.72	1.38	0.014	0.25	18

TABLE 1.—ANALYTICAL DATA FOR PROFILES ON SITES NO. 1 TO NO. 12. RESULTS EXPRESSED ON OVEN DRY BASIS—*Continued*

Horizon or layer	Depth	pH	Loss-on-ignition	Nitrogen	Carbon	C/N
			%	%	%	
Site 3. Granular mor. White spruce on podzol.						
LL	0 to ¼ in.	5.52	94.13	1.27	49.60	39
H	¼ to 3 in.	4.70	84.03	2.11	47.75	23
A_1	3 to 3½ in.	5.52	32.40	0.82	16.76	21
A_2	3½ to 10 in.	5.55	1.69	0.020	0.54	27
B_1	10 to 24 in.	4.24	4.94	0.046	0.73	16
B_2	24 to 36 in.	4.31	1.54	0.010	0.27	27
Site 4. Matted mor. Aspen on podzol.						
F	0 to ¼ in.	5.76	77.94	1.95	43.40	22
H	¼ to 2½ in.	6.00	69.00	2.09	38.50	19
A_1	2½ to 4 in.	5.40	10.24	0.356	5.96	17
A_2	4 to 8 in.	5.22	1.47	0.050	0.51	10
B_1	8 to 16 in.	5.65	2.62	0.044	0.64	14
Site 5. Matted mor. Aspen on podzol.						
LL	—	5.59	83.95	1.27	43.20	34
F	0 to ¼ in.	6.20	79.61	1.96	43.80	22
H	¼ to 2 in.	5.70	56.80	1.61	31.30	19
A_2	2 to 8 in.	4.85	2.07	0.046	0.65	15
B_1	8 to 14 in.	5.00	3.37	0.047	0.63	13
B_2	14 to 22 in.	4.95	1.99	0.029	0.40	14
Site 6. Matted mor. Birch on podzol.						
F	0 to ¼ in.	5.90	89.75	2.34	42.40	18
H	¼ to 1½ in.	5.50	82.74	2.34	42.65	18
A_1	1½ to 1¾ in.	4.60	38.65	1.24	21.45	17
A_2	1¾ to 5 in.	4.40	2.15	0.066	0.98	15
B_1	5 to 15 in.	5.40	0.86	0.020	0.34	17
Site 7. Matted mor. Balsam poplar on podzol.						
LL	—	5.70	90.17	1.63	40.40	25
H	0 to 4 in.	5.80	81.64	2.30	39.60	17
A_2	4 to 24 in.	5.70	0.85	0.009	0.48	50
B_1	24 in. +	5.46	1.64	0.007	0.39	56
Site 8. Dry mor. Jack pine on podzolized sand.						
LL	—	4.50	95.08	0.91	41.40	46
H	0 to ¼ in.	4.71	74.62	1.27	37.10	29
A_2	¼ to 1 in.	5.10	4.71	0.080	2.55	33
B	1 to 2½ in.	5.30	1.21	0.027	1.33	49
C	2½ in. +	6.12	0.55	0.010	0.11	11
Site 9. Dry mor. Jack pine on podzolized sand.						
LL	—	4.30	88.63	0.99	41.70	42
A_1	0 to ¼ in.	4.70	12.35	0.222	6.86	31
A_2	¼ to 2½ in.	5.86	2.45	0.048	1.84	38
B	2½ to 5 in.	6.00	1.03	0.007	0.68	97
C	5 in. +	5.48	0.60	0.010	0.25	25

TABLE 1.—ANALYTICAL DATA FOR PROFILES ON SITES NO. 1 TO NO. 12. RESULTS EXPRESSED ON OVEN DRY BASIS—*Concluded*

Horizon or layer	Depth	pH	Loss-on-ignition	Nitrogen	Carbon	C/N
			%	%	%	
Site 10. Shallow peat. Black spruce on lacustrine clay.						
LL	—	5.36	89.78	1.19	39.70	33
1	0 to 3/4 in.	4.80	82.60	1.59	38.10	24
2	3/4 to 5 1/2 in.	5.35	85.96	1.68	41.20	24
A	5 1/2 to 12 in.	7.29	36.46	1.27	29.60	24
B	12 to 16 in.	7.62	5.80	0.256	3.37	13
C	16 to 24 in.	7.73	1.97	0.035	0.43	12
Site 11. Shallow peat. Willow on alluvial silty clay.						
1	0 to 1/4 in.	6.44	89.30	2.10	39.30	19
2	1/4 to 3 in.	7.56	76.58	2.46	39.10	16
A	3 to 13 in.	6.95	31.30	0.77	12.30	16
B	13 to 25 in.	8.08	16.60	0.54	5.08	9
C	25 to 36 in.	8.00	6.70	0.206	1.61	7
Site 12. Sphagnum peat. Tamarack.						
LL	—	4.64	95.32	0.76	43.60	52
1	0 to 4 in.	3.95	94.53	1.05	41.20	39
2	4 to 8 in.	4.75	89.25	1.32	41.30	31
3	8 to 10 in.	4.12	78.61	1.72	40.25	23
C	10 to 30 in.	5.25	0.86	0.03	0.35	12

pH Values

The granular and dry mor types are more acid than matted mor. The pH of granular mor decreases with decomposition of leaf litter. There is an increase in pH with decomposition of leaf litter in both dry mor and matted mor, but the H layer of matted mor is more acid than the F layer. The litter and H layer of granular mor on a rendzina-like soil (pH 8) are the same as the organic layers of granular mor on podzol soils. Organic layers of dry mor were more acid than the underlying soil horizons while the matted mor humus layers were less acid than the underlying soil horizons. Shallow peat, developed under black spruce on a calcareous soil, was quite acid while shallow peat developed under willow on a calcareous soil was close to neutral in reaction. The tamarack-sphagnum peat layers were very acid.

Loss-on-Ignition (Ash Content)

Loss-on-ignition can be used as a measure of total organic matter in forest floors and also gives the percentage of ash present. Litter under deciduous trees is higher in mineral content than litter under conifers. Humus layers of matted and dry mor are higher in mineral content than the corresponding layers in granular mor. The high ash content of the H layers in granular and dry mor may be due partly to mixing with the underlying mineral soil. There was evidence of sand particles mixed in with the H layer in dry mor.

The Nitrogen Content

Table 1 shows the total nitrogen content for the forest floor layers and peats and their related soil horizons. Litter developed under jack pine and tamarack was considerably lower in total nitrogen than litter from the other tree varieties. The humus layers were higher in nitrogen than the leaf litter from which these layers were derived. Humus layers in the dry mor type were noticeably lower in total nitrogen than humus layers in granular or matted mor. Nitrogen content of the peats also increased with the depth of the peaty layers.

The distribution of nitrogen fractions (water soluble, HCl hydrolyzable, and "lignin-nitrogen") in the 3 mor forest floor types was also determined and representatives of each type with their fractional analysis are shown in Table 2. The amount of nitrogen recovered in the portion hydrolyzed by H_2SO_4 was negligible, the highest recovery being 0.03% with no recovery for most of the samples.

TABLE 2.—DISTRIBUTION OF THE NITROGEN FRACTIONS OF REPRESENTATIVE MOR FOREST FLOORS

Type of forest floor	Tree variety and site no.	Layer	Water soluble nitrogen	HCl hydrolyzable nitrogen		Lignin nitrogen	Total % nitrogen	Nitrogen unaccounted for
				Nonamide	Amide			
Granular mor	W. spruce 3	LL	0.13	0.21	0.07	0.97	1.27	−0.11
Granular mor	W. spruce 3	H	0.00	0.47	0.14	1.62	2.11	−0.03
Dry mor	Jackpine 8	LL	0.00	0.01	0.05	0.83	0.91	0.03
Dry mor	Jackpine 8	H	0.03	0.02	0.17	1.22	1.27	−0.05
Fibrous mor	Aspen 5	LL	0.00	0.00	0.07	1.01	1.27	0.19
Fibrous mor	Aspen 5	F	0.00	0.02	0.11	1.88	1.96	−0.05
Fibrous mor	Aspen 5	H	0.00	0.00	0.14	1.39	1.61	0.08

With the exception of litter under white spruce, there was little or no water soluble nitrogen present. In fibrous and dry mor almost all of the nitrogen hydrolyzed by dilute HCl was of an amide (NH_3) nature. The granular mor had practically the same amount of amide nitrogen and, in addition, had a fair amount of non-amide nitrogen in the dilute HCl fraction. The % of amide nitrogen increased with degree of decomposition in all 3 mor types. Almost all of the nitrogen in fibrous and dry mor, and over 75% of the nitrogen in granular mor, remained insoluble in hot mineral acids and was recovered in the complex lignin-nitrogen fraction.

The Organic Carbon Content

No inorganic carbonates were found in the forest floor layers, and so all of the carbon present was in the organic form. The interest in organic carbon centers primarily around the more or less definite ratios between carbon and nitrogen, and carbon and organic matter in the soil.

The C/N Ratios

From Table 1 it is seen that C/N ratios for leaf litter varied from 25 for balsam poplar to 52 for tamarack, with an average of 39. Conifer litter

had a higher C/N value than the litter of deciduous trees. The C/N ratios for humus layers of granular and dry mor averaged about 27 and were higher than the C/N ratios for humus layers of matted mor with an average value of 19. The shallow peat layers had a C/N ratio close to 20 while this ratio was wider for sphagnum peat. The average C/N ratio for all podzol samples was 22 which is very close to the ratios found by Anderson and Byers (1).

The Factor for Calculating Total Organic Matter

Loss-on-ignition data from organic materials such as peat soils and organic horizons of forest soils are very close to an exact measure of total organic matter (7). Table 3 gives factors to convert organic carbon percentages to total organic matter percentages. These factors were obtained by dividing loss-on-ignition values by the % of organic carbon in the sample.

TABLE 3.—CONVERSION FACTORS FOR CALCULATING PERCENTAGE OF ORGANIC MATTER FROM A KNOWLEDGE OF PERCENTAGE ORGANIC CARBON IN ORGANIC MATERIALS

Mor type	Layers		
	LL	F	H
Dry mor	2.20	—	2.01
Granular mor	1.90	—	1.79
Matted mor	2.08	1.93	1.90
Average	2.06	1.93	1.87

The average values obtained in Saskatchewan are slightly higher than those obtained by other workers (3, 7, 11, 18). The factors for dry mor are considerably higher than for any other mor type, being close to the factor of 2.14 which was obtained for peats in Saskatchewan. The factors for granular mor are very close to factors found by Lunt (7).

DISCUSSION OF THE ORGANIC CONSTITUENTS

Since the primary interest is in the composition of organic matter, the % of the various fractions separated will be discussed as a % of the organic matter rather than as a % of the total sample. Loss-on-ignition values for leaf litter, humus layers, and peats is regarded as being the most reliable approximation to organic matter content, so values given in the following discussions will be on an oven-dry, ash-free basis. The organic matter of the A_1 horizons is calculated using the factor 1.724. Recoveries of organic constituents for 30 samples analyzed varied from 87.66% to 102.22% with an average recovery of 95.79%. These results compare favourably with results reported by Waksman and Stevens (13) which accounted for 85 to 98% of the constituents. All values given will be also calculated on the basis of 100% recovery to make comparisons between samples somewhat easier. Table 4 presents the % of organic constituents in organic matter of forest floors, peats, and A_1 horizons.

TABLE 4.—PERCENTAGE OF ORGANIC CONSTITUENTS

Layer or horizon	Ether-soluble	Alcohol-soluble	Water-soluble	Hemi-celluloses	Cellulose	Lignin	Nitrogen complexes ($N_2 \times 6.25$)
	%	%	%	%	%	%	%
Site 1. Granular mor under white spruce on podzol.							
H	1.65	5.05	5.81	22.50	8.32	41.57	15.10
Site 2. Granular mor under white spruce on rendzina-like profile.							
LL	3.92	4.11	9.03	21.16	14.30	39.02	8.46
H	1.81	3.10	6.21	23.65	9.29	44.82	11.12
A_1	.81	1.07	3.72	16.63	3.81	58.90	15.16
Site 3. Granular mor under white spruce on podzol.							
LL	11.37	4.57	5.58	22.95	14.10	32.86	8.57
H	3.57	4.29	7.17	23.58	8.66	36.22	16.51
A_1	.85	1.60	4.88	22.61	5.49	49.26	15.43
Site 4. Matted mor under aspen on podzol.							
F	4.47	4.64	6.03	22.85	9.30	35.77	16.99
H	2.33	3.16	7.40	19.98	7.92	38.76	20.45
Ste 5. Matted mor under aspen on podzol.							
LL	6.55	8.75	7.57	23.55	16.70	26.85	9.83
F	4.33	4.73	5.59	23.00	10.38	35.12	16.85
H	2.29	4.22	4.86	22.59	10.17	37.92	17.91
Site 6. Matted mor under birch on podzol.							
F	4.44	4.31	8.37	25.03	12.50	27.65	17.50
H	2.46	5.38	7.60	22.84	9.45	32.72	19.55
A_1	2.76	3.66	4.88	16.28	5.66	47.76	19.00
Site 7. Matted mor under balsam poplar on podzol.							
LL	7.83	4.53	8.83	20.90	14.76	30.80	12.35
H	2.34	3.75	8.96	20.32	9.16	36.07	19.40
Site 8. Dry mor under jack pine on podzolized sand.							
LL	6.69	4.94	6.80	23.95	22.12	29.53	5.97
H	3.63	3.97	8.40	21.41	15.53	36.01	11.05
Site 9. Dry mor under jack pine on podzolized sand.							
LL	5.63	4.35	8.85	23.45	17.13	33.49	7.10
Site 10. Shallow peat under black spruce on calcareous soil.							
LL	6.01	4.56	6.21	24.95	19.35	30.31	8.61
1	4.81	5.42	9.78	20.78	14.09	32.20	13.02
2	1.53	2.80	8.14	20.80	7.89	45.92	12.92

TABLE 4.—PERCENTAGE OF ORGANIC CONSTITUENTS—*Continued*

Layer or horizon	Ether-soluble	Alcohol-soluble	Water-soluble	Hemi-celluloses	Cellulose	Lignin	Nitrogen complexes ($N_2 \times 6.25$)
Site 11. Shallow peat under willow on calcareous soil.							
1	3.89	6.05	9.12	20.82	10.93	32.19	17.00
2	1.31	2.34	6.40	18.32	8.96	40.81	21.86
A_1	.11	.71	4.43	19.40	4.16	53.94	17.25
Site 12. Sphagnum-peat with tamarack.							
LL	9.86	13.71	16.66	20.31	11.76	22.44	5.26
1	1.90	5.54	12.28	41.76	16.36	15.34	6.82
2	2.09	2.86	5.68	47.25	15.60	16.94	9.86
3	2.15	3.03	7.28	33.03	9.63	29.77	15.11

The Ether-Soluble Materials (Fats and Waxes)

The amounts of ether-soluble materials present in matted and dry mor are quite similar. These materials are also neutral to litmus. Granular mor is quite variable in ether-soluble material content and these materials are slightly acid to litmus. The shallow peats are somewhat similar to the forest floors in amount of ether-soluble materials present. The waxes and fats in sphagnum peat must be of a nature resistant to decomposition by micro-organisms, for on referring to Table 4, we see that these materials which are soluble in ether increase slightly whereas they decrease fairly rapidly down the profile in forest floors and shallow peats.

The Alcohol-Soluble Materials

The alcohol-soluble materials were brown in colour and slightly acid to litmus. The % of these materials in all mor types is about the same. In all forest floor types, excepting matted mor under birch, the alcohol-soluble materials decrease in amount with decomposition. This is true also for the shallow peats. The alcohol-soluble substances in sphagnum peat decrease during the initial stages of decomposition, but seem to resist further breakdown. This would indicate that some of the materials are easily decomposed while others are quite resistant to attack by micro-organisms. The leaf litter of tamarack and aspen is considerably higher in alcohol-soluble materials than that of any other tree varieties. Tamarack needles are particularly high in these materials being slightly higher than needles of *Pinus strobus* (white pine) reported by Waksman (13).

The Water-Soluble Fraction

There seems to be little difference between the forest floor types and shallow peats with regard to the amount of water-soluble materials present. In sphagnum peat the water-soluble substances decreased markedly from layer 1 to layer 2, but there was an increase in the third layer.

The Hemicellulose Fraction

The hemicelluloses of plant residues are made up chiefly of pentosans, hexosans and polyuronides. Pentosans decompose fairly slowly (15, 16), and of the two most common hexosans, mannin decomposes quite readily while galactin is very resistant to decomposition. Polyuronides increase on decomposition of plant remains because of extensive synthesis by micro-organisms. An understanding of these facts is necessary to interpret the data in Table 4.

In granular mor the hemicellulose content increases with decomposition, presumably because of a high proportion of the resistant hexosan galactin or because of extensive synthesis of polyuronides by the type of micro-organisms present. In the other forest floor types, the amount of hemicelluloses decreases with decomposition probably because of a higher % of pentosans and the hexosan mannin. Jack pine litter is higher in hemicellulose than the litter of any of the other upland forest trees. The hemicellulose content of black spruce and tamarack litter, and of the shallow peats is not unlike that of the upland forest floors. Sphagnum peat contains over twice as much hemicellulose as the other peats. Almost half of the sphagnum peat in the upper layers consists of hemicelluloses. These hemicelluloses seem to be somewhat resistant to decomposition as they increase in layer 2, but they do decrease in layer 3. It is probable that layer 3 did not originate directly from the sphagnum but rather from earlier plants (cat-tails, sedges, etc.), which started the bog formation. We would therefore expect the composition of this layer to be different from that of the first two layers.

The Cellulose Fraction

Cellulose, being one of the main energy sources for micro-organisms, is broken down rapidly during decomposition of leaf litter. There is a decrease of 30 to 40% in cellulose from the leaf litter to the H layer in all the forest floor types and shallow peats. There is a slight decrease in cellulose content of sphagnum peat from layer 1 to layer 2, and then a sharp decrease from layer 2 to layer 3, again suggesting the possibility of some different origin for layer 3.

The Lignin Fraction

The lignin content in granular mor increased about 12% from the LL to the H layer. In dry mor, the lignin increased about 20% from the LL to the H layer while in matted mor the lignin content increased almost 30%. For matted mor types, where F layers were present, the lignin content increased about 10% from the F to the H layers. In shallow peat, there was quite a rapid increase in lignin content with increasing depth. In sphagnum peat we find very little increase from layer 1 to layer 2 and then a very large increase in layer 3 which again indicates that layer 3 is of different origin to layers 1 and 2.

The Nitrogenous Complexes

If these complexes are assumed to be somewhat similar in composition to the proteins of plant and animal residues, the factor of 6.25 can be used to convert % nitrogen to % of nitrogenous complexes. Since nitrogen

content of the various samples was discussed previously there is only one point left to discuss here. It has been demonstrated by Waksman (17) that protein and lignin form a resistant complex which possesses the various chemical, physico-chemical, and biological characteristics of soil humus so it was thought that possibly there would be some relation between the amount of lignin and nitrogen present in the more highly decomposed H layers. Lignin and nitrogen content do increase as the litter is decomposed, but they do not reach a constant ratio for the humus layers studied here.

CHANGES IN ORGANIC CONSTITUENTS DURING DECOMPOSITION OF FOREST FLOORS

If the soil humus in all soils is made up of similar organic complexes, then the final decomposition products of leaf litter should be somewhat similar in composition. In an effort to see if this occurs, the organic matter of the humus layers and A_1 horizons of 4 widely varying forest and soil types was analysed. The types chosen for this study were granular mor on heavy textured podzol (site 3) and rendzina-like (site 2) soil types, matted mor on a podzol (site 6) soil and shallow peat (site 11) on a medium textured calcareous soil. The data is presented in Table 4.

The % of ether-soluble materials in the leaf litter and F layers varied considerably but in the A_1 horizon for 3 sites the % of these materials is almost the same. For all sites, the ether-soluble materials decreased down through the profile and seem to be still on the decrease in the A_1 horizon.

For the alcohol and water soluble materials, a somewhat similar condition exists. The content of these materials in the LL, F, and H layers varies considerably. In some instances, we find an increase in these materials with increasing depth of the forest floor. However, in all sites the alcohol and water-soluble materials decrease quite noticeably when we reach the A_1 horizon. This decrease is somewhat less in the podzol soils but the evidence tends to show that these materials are still decreasing in the A_1 horizon.

The cellulose content of these widely varying forest and soil types is very much the same and it is still on the decrease in the A_1 horizon, but with hemicelluloses widely varying results occur, as can be seen from Table 4. The only explanation to account for this is the fact that hemicelluloses consist of compounds differing in their chemical composition and resistance to decomposition. Because of the varying soil conditions, we may have conditions existing in one site which favour the decomposition of hemicelluloses by micro-organisms, whereas in another site conditions may prevail which favour the synthesis of hemicelluloses.

It has been shown earlier that nitrogenous complexes increase with decomposition of leaf litter in the forest floor. In the A_1 horizon we note that for some sites there is a decrease in % nitrogen in the organic matter. A point worthy of mention is that in general the nitrogen content of the organic matter seems to be going towards a constant value giving a ratio of C/N varying between 17.5 for willow to 26.5 for white spruce (site 3) with an average C/N ratio of 21.5.

The most noticeable change, as decomposition of organic materials in forest floors proceeds, is the increase in lignin content. There is a very marked increase in lignin from the H layer to the A_1 horizon. This increase

seems to be much greater here than results obtained by Shewan (11) and Waksman (18) and supports the theory that lignin is one of the "mother" substances of soil humus.

SUMMARY

Investigations concerned with the classification of forest floors in Saskatchewan have been carried out and the following observations have been made:—(1) A lighter leaf fall and thinner organic mat development is observed in Saskatchewan forests than in forests of northeastern United States. (2) The forest floors of Saskatchewan belong to the mor group. Three mor types were encountered; namely, granular, matted, and dry mor. The latter occurred under jack pine. The name "dry" mor has been suggested due to the very thin nature of this forest floor type and the existing classifications do not include a type similar to this.

Chemical analysis of forest floors in Saskatchewan reveals that:—(1) The granular and dry mor types are more acid than matted mor. (2) Humus layers of matted and dry mor are higher in mineral content than the corresponding layers in granular mor. (3) Litter under deciduous trees is higher in mineral content than litter under conifers. (4) Humus layers in dry mor are lower in total nitrogen than humus layers in granular or matted mor. (5) Almost all of the nitrogen in matted and dry mor was recovered in the resistant lignin fraction but in granular mor about 25% of the nitrogen was hydrolyzed by dilute acid and boiling water. (6) The C/N ratios for humus layers of granular and dry mor are higher than the C/N ratios for humus layers of matted mor. (7) The factor to calculate % of organic matter from % of organic carbon is highest for dry mor and lowest for granular mor. (8) No consistent differences were noted between different forest floor types as regards amount of ether-, alcohol-, and water-soluble materials. The ether-soluble materials decrease fairly rapidly as the leaf litter is decomposed and these materials in granular mor are slightly acid to litmus. (9) For granular mor hemicelluloses increase with decomposition of the leaf litter whereas this fraction decreases with decomposition of the litter of other mor types. (10) For all forest types there is a rapid decrease in cellulose content with decomposition of the leaf litter. (11) There is a steady increase in lignin content of the organic matter with decomposition of leaf litter.

Shallow peats are quite similar to forest floors in chemical composition. Chemical analysis of sphagnum peat shows a very high hemicellulose content.

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REFERENCES

1. Anderson, M. S. and H. G. Byers. The carbon-nitrogen ratio in relation to soil classification. Soil Sci. 38 : 121-138. 1934.
2. Blish, M. J. and R. M. Sandstedt. An improved method for the estimation of flour diastatic value. Cereal Chem. 10 : 189-202. 1933.
3. Gortner, R. A. The organic matter of the soil. I. Some data on humus, humus carbon, and humus nitrogen. Soil Sci. 2 : 395-441. 1916.
4. Halliday, W. E. D. A forest classification for Canada. Dept. of Mines and Resources. Ottawa. Forest Services Bull. 89.
5. Heiberg, S. O. and R. F. Chandler, Jr. A revised nomenclature of forest humus layers for the north-eastern United States. Soil Sci. 52 : 87-100. 1941.
6. Joffe, J. S. Pedology. Rutgers Univ. Press. New Brunswick, N.J. 1936.
7. Lunt, H. A. The carbon-organic matter factor in forest soil humus. Soil Sci. 32 : 27-33. 1931.
8. Lunt, H. A. Definitions of forest humus types. Rpt. 16th Ann. Meet. Amer. Soil Sur. Ass. Bull. 17 : 43. 1936.
9. Mitchell, J., H. C. Moss, and J. S. Clayton. Soil survey of southern Saskatchewan. Soil Sur. Rpt. 12. Univ. of Sask. 1944.
10. Monthly Record of Meteorological Observations. Dept. of Tpt. Met. Div. of Air Services. Toronto.
11. Shewan, J. M. The proximate analysis of the organic constituents in northeast Scottish soils, with some notes on methods. Jour. Agr. Sci. 28 : 324-340. 1938.
12. The Canada Year Book. 1945.
13. Waksman, S. A. and K. R. Stevens. Contributions to the chemical composition of peat. I. Chemical nature of organic complexes in peat and methods of analysis. Soil Sci. 26 : 113-139. 1928.
14. Waksman, S. A. and K. R. Stevens. A critical study of the methods for determining the nature and abundance of soil organic matter. Soil Sci. 30 : 97-116. 1930.
15. Waksman, S. A. and R. A. Diehm. On the decomposition of hemicelluloses by microorganisms. II. Decomposition of hemicelluloses by fungi and actinomyces. Soil Sci. 32 : 97-117. 1931.
16. Waksman, S. A. and R. A. Diehm. On the decomposition of hemicelluloses by microorganisms. III. Decomposition of various hemicelluloses by aerobic and anaerobic bacteria. Soil Sci. 32 : 119-139. 1931.
17. Waksman, S. A. and K. R. N. Iyr. Contribution to our knowledge of the chemical nature and origin of humus. I. On the synthesis of the "Humus nucleus." Soil Sci. 34 : 43-69. 1932.
18. Waksman, S. A. and I. J. Hutchings. Chemical nature of organic matter in different soil types. Soil Sci. 40 : 347-362. 1935.

MOISTURE RELATIONSHIPS OF THE WHEAT STEM SAWFLY (*CEPHUS CINCTUS* NORT.)

I. SOME EFFECTS OF DESICCATION[1]

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A frequently repeated concept of insect control is that the control measures are likely to be most successful if applied at the time when the species is most susceptible. In the case of the wheat stem sawfly (*Cephus cinctus* Nort.) one means of cultural control which has met with some measure of success is shallow tillage. The object of this operation is to loosen the wheat stubble and deposit it on the soil surface where it is more exposed to desiccation and high temperatures. The experiments reported here are the result of an attempt to find at which stage or at what time the insect is most susceptible to these conditions.

Shortly before the wheat is ready to harvest, the larva girdles the inside of the wheat stem, approximately at the soil surface. The stem, being weakened at this point, breaks off and falls, leaving a short stubble, or "stub," into which the larva has meanwhile retired, plugged the open end with frass, and lined with the translucent cocoon. The species spends about 10 months out of each year in the stub. As most stubs are 1 to 2 in. in length, the larvae can move up and down in response to temperature changes, thus escaping intense soil surface heat or taking advantage of warm sunshine at a time when the soil is still cold.

Larvae are in a state of diapause in the fall, but during the fall and winter this is gradually eliminated, and by spring they are ready for further morphological development. They change first to prepupae, then to unpigmented pupae which gradually become coloured, and finally to adults, all inside the stubs. The adults may leave the stubs at once or remain in them for some time, depending on climatic conditions (Manson 1934).

MATERIALS AND METHODS

Constant temperatures were maintained in cabinets with an accuracy of approximately $\pm 1.0°$ C. Constant humidities were obtained by the use of sulphuric acid and water mixtures in glass containers of 1 to 8 quart capacity.

When specimens were exposed while still in the stubs, the latter were stripped clean of loose dirt and leaves and the dried roots were clipped off. They were then exposed in loosely packed lots of 30 to 60 in screen-wire cups.

The moisture content of a sample was considered equivalent to the weight lost in an electric oven at 95° to 100° C. in 24 hours, at which time the dry weight had reached a constant minimum.

Stubs were obtained fresh from the field in the spring and fall. For winter work stubs were collected in the fall and stored in a root cellar until needed.

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EXPERIMENTAL RESULTS

Naked Larvae at 30° C.

Initial tests were made at 30° C. (86° F.) and relative humidities of 0 to 50%. The larvae, which were in a state of diapause, were removed from their stubs and cocoons so that they could be observed and weighed regularly. They were exposed in open 5 by 40 mm. vials, a procedure that was later discontinued as the vials were considered too long for adequate ventilation. Nevertheless, these tests are comparable with each other, and the results are presented graphically in Figure 1. It will be seen that under the conditions of the experiment all larvae lost weight rapidly at first but more slowly after about 10 days. As expected, larvae lost weight more quickly as the relative humidity decreased. Mortality was negligible until larvae had lost at least 40% of their initial weight, after which time they quickly succumbed. For this reason, the curves in Figure 1 are carried only to an average 40% weight loss. Up to this point fewer than 10% of the specimens died, and virtually all of these had already lost over 40% of their initial weight.

Although larvae lost weight readily under these temperature and moisture conditions, they survived for a surprisingly long time when it is considered that they were removed from the protection of their cocoons and stubs. If they had been exposed in their natural state, it would have taken considerably longer to produce any mortality. It appears certain that a temperature of 30° C., in itself, has no lethal effect on sawfly larvae in diapause. The larvae definitely died of desiccation and then only after losing over 40% of their initial weight.

Naked Larvae at 35° C.

A series of tests similar to those at 30° C. was run at 35° C. Except that the higher temperature resulted in a correspondingly faster rate of desiccation, the results were practically the same. The mortality and progressive weight loss at 7 relative humidities from 0 to 60% are listed in Table 1. As at 30° C., it is seen that the larvae lost weight faster and died sooner as the relative humidity decreased. Again, it seems unlikely that temperature alone had any lethal effect, except indirectly through its role in desiccation.

While Table 1 seems to indicate that some larvae died before losing 40% of their initial weight, this is not actually the case even at 60% R. H., as the values listed are averages based on the weight loss of survivors only. Table 2 shows that the weight loss at death averaged considerably more than 40%. These values, especially those for 0% R. H., are maxima, since the larvae inevitably lost some weight between the actual time of death and the time of weighing, a period of up to 48 hours. For all practical purposes, larvae may be considered near death from desiccation after losing 40% of their original weight. Actually, such factors as initial moisture content and the nutritional and physiological state of the specimens account for variation in the data.

Table 2 also lists the average longevity of the test larvae, which, as in the similar tests at 30° C., were exposed naked in 5 × 40 mm. open vials. The longevity alone shows that mortality is due to desiccation, and not

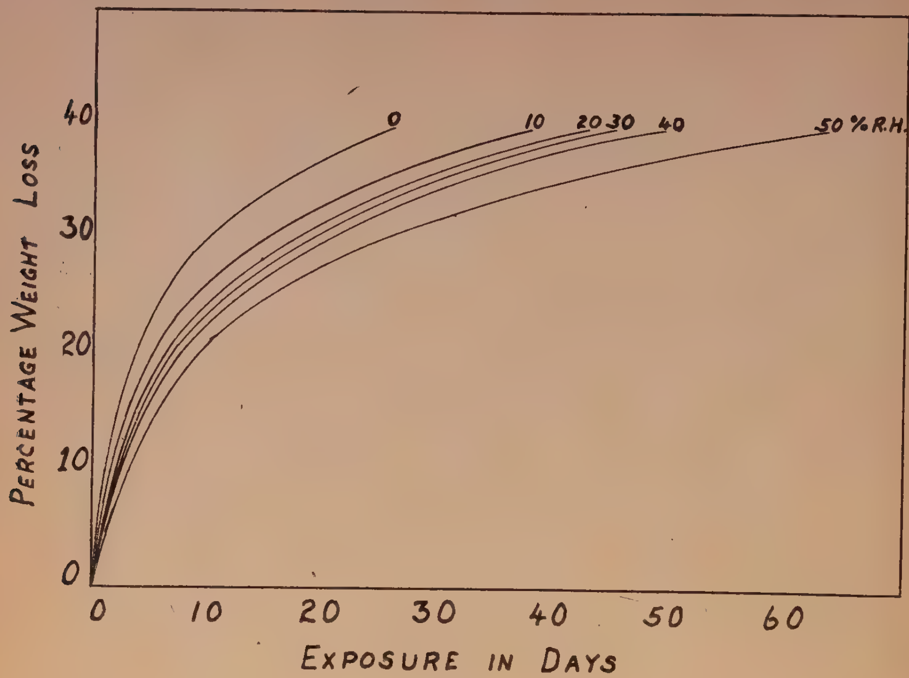

Figure I

high temperature. Desiccation at any particular temperature and humidity, or at a certain vapour pressure deficit, is a function of time. That time also had no effect in itself is also shown in Table 2, where the values for weight loss, dry matter content, and moisture content, are virtually constant throughout the relative humidity range from 0 to 60% R. H. (allowance being made in the extreme case at 0% R. H. for weight loss occurring after death but before weighing).

Naked Larvae at 40° C.

It has already been seen that mortality of naked *Cephus cinctus* larvae at 30° C. (0 to 50% R. H.) and at 35° C. (0 to 60% R. H.) resulted entirely from desiccation. At 40° C. (104° F.) the same conclusion was reached for relative humidities up to 80%. In this series, larvae were exposed in a more open type of container, consisting of sealing-wax trays with moulded depressions to keep the larvae isolated. At 0% and 10% R. H. the naked larvae dried, died, and continued to dry out so fast that accurate weighing was impossible. Approximate data were obtained for relative humidities of 20% and 40% to 80%.

The longevity was cut considerably by the 5° C. rise in temperature and the more open exposure. Nevertheless, in this short time the weight loss was at least as great as during the longer exposures at 30° and 35° C. At 20 to 60% R. H. the weight loss values are undoubtedly too high, because of drying after death but before weighing (in this experiment, less than 24 hours). The values at 70 and 80% R. H. are considered approximately

correct. The same conclusion is therefore drawn, as at 30° and 35° C., that death is due to desiccation, and occurs only after 40% of the original weight has been lost.

EFFECTS OF DESICCATION ON NAKED LARVAE

The experiments thus far reported have led to the conclusion that mortality of naked *Cephus cinctus* larvae under the conditions described is caused by desiccation. While the point at which the loss of moisture becomes fatal varies among individuals as a result of their previous history, it is certainly not far away when 40% of the initial weight has been lost. This situation held regardless of humidity within the limits used. Ludwig (1937) found that with Japanese beetle larvae, prepupae and pupae, death occurred at approximately the same water content, regardless of the rate of desiccation. In each case, water loss appears to be the limiting factor in survival. Whether larvae can closely approach lethal desiccation and yet recover when supplied with contact moisture is the subject of another paper.

The composition of material lost during desiccation is of some interest. It is predominantly water, but there is also a very appreciable loss of dry matter. The latter, of course, is not lost as such but as products of katabolism, principally water and carbon dioxide. This metabolic water is probably available to certain tissues and thus of some assistance in delaying fatal desiccation. Even in diapause, sawfly larvae do a considerable amount of "squirming" so that there is muscular activity as well as metabolic activity, though the latter is probably at a low level compared with actively developing forms.

Table 4 lists the averaged losses of total weight, water and dry matter of the specimens reported in Table 2, with the exception of those held at 0% R. H.

Values for initial moisture and dry matter contents are estimated, as it was of course impossible to obtain them from the actual specimens being desiccated. On the basis of larvae of similar stock, it was estimated that their moisture content averaged close to 54%, and this is the value used in Table 4.

Larvae lost an average of 46% of their weight before death. In doing so, their moisture content decreased by 61% and their dry matter content by 35%, resulting in a final moisture content of 38.5% and a final dry matter content of 61.5%. Thus, during desiccation the moisture content decreases in amount and in terms of percentage of body weight, whereas dry matter decreases in amount but increases in terms of percentage of body weight. This reversal of relative proportions of moisture and dry matter calls for care in the interpretation of data dealing with them. A mere statement of the percentage of moisture or dry matter may be adequate in some cases, particularly if the experimental material is carefully selected for uniformity. There are, however, many possibilities which are easily misinterpreted. An insect may lose both moisture and dry matter in such proportion as to retain its original percentage moisture content or dry

TABLE 1.—MORTALITY AND PROGRESSIVE WEIGHT LOSS (OF SURVIVORS) IN GROUPS OF 10 LARVAE EXPOSED TO 35° C. AND RELATIVE HUMIDITIES OF 0% TO 60%

Exposure	0% R. H.		10% R. H.		20% R. H.		30% R. H.		40% R. H.		50% R. H.		60% R. H.	
	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss	Mortality	Weight loss
Days		%		%		%		%		%		%		%
2	2	35.9	0	25.1	0	22.5	0	21.5	0	17.1	0	12.1	0	9.2
3	4	42.1	—	—	—	—	—	—	—	—	—	—	—	—
4	5	44.6	0	31.5	0	27.8	0	26.7	0	22.7	0	17.0	0	14.3
5	6	47.8	—	—	—	—	—	—	—	—	—	—	—	—
6	8	43.7	0	34.3	0	29.8	0	29.6	0	25.2	0	19.6	0	17.3
7	9	47.2	—	—	—	—	—	—	—	—	—	—	—	—
8	—	—	0	36.9	0	32.0	0	32.5	0	28.0	0	21.9	0	19.4
11	—	—	1	38.4	1	34.7	1	34.6	0	30.6	0	24.9	0	22.1
14	—	—	2	40.1	2	36.2	1	36.9	0	32.6	0	26.7	0	23.2
16	—	—	4	41.3	2	37.8	1	39.0	0	34.2	0	28.0	0	23.9
18	—	—	4	43.3	3	36.9	1	40.4	1	33.7	0	29.3	0	24.8
20	—	—	5	43.5	3	37.2	4	39.0	1	34.5	0	30.3	0	26.1
22	—	—	5	45.0	4	38.9	4	41.2	1	35.7	0	31.7	0	26.7
24	—	—	6	46.8	4	39.5	6	40.0	1	36.1	0	32.1	0	26.8
26	—	—	6	48.3	4	40.5	6	41.3	1	36.9	0	33.3	0	27.2
28	—	—	9	39.8	5	40.0	8	41.9	2	37.2	0	34.5	0	28.5
30	—	—	10	40.6	5	41.8	8	43.5	3	36.8	0	34.9	0	29.3
32	—	—	—	—	6	42.5	9	41.2	4	37.2	1	36.0	0	30.7
34	—	—	—	—	7	41.3	9	44.3	4	37.2	1	36.0	0	30.7
36	—	—	—	—	8	40.5	9	48.7	4	38.6	1	37.6	—	—
38	—	—	—	—	8	42.0	9	48.7	4	39.1	1	38.4	0	32.0
40	—	—	—	—	8	42.8	10	49.7	5	38.1	1	39.6	—	—
42	—	—	—	—	8	45.5	—	—	5	39.4	1	40.2	0	33.5
44	—	—	—	—	10	45.7	—	—	5	40.3	1	41.0	—	—
46	—	—	—	—	—	—	—	—	5	41.7	2	42.2	—	—
48	—	—	—	—	—	—	—	—	5	42.3	5	43.2	0	35.7
50	—	—	—	—	—	—	—	—	5	43.2	5	44.0	—	—
53	—	—	—	—	—	—	—	—	8	42.0	7	43.3	—	—
56	—	—	—	—	—	—	—	—	8	43.2	10	43.3	2	31.1
58	—	—	—	—	—	—	—	—	10	43.2	—	—	—	—
64	—	—	—	—	—	—	—	—	—	—	—	—	5	35.7

TABLE 2.—SUMMARIZED ANALYSIS OF DATA; LARVAE EXPOSED TO 35° C. AND RELATIVE HUMIDITIES OF 0 TO 60%

(Initial moisture content 54%, dry matter content 46%, estimated)

—	Relative humidity						
	0%	10%	20%	30%	40%	50%	60%
Average longevity (days)	4.2	20.7	27.6	24.1	41.6	49.0	71.5
At death, percentage:							
Weight loss	48.0	46.2	46.5	45.9	46.6	45.5	45.0
Dry matter (basis—initial weight)	36.6	33.8	34.2	32.7	31.3	33.1	33.1
Moisture (basis—initial weight)	15.4	20.0	19.3	21.4	22.1	21.4	21.9
Dry matter (basis—death weight)	70.4	62.9	63.8	60.5	58.7	60.8	60.2
Moisture (basis—death weight)	29.6	37.1	36.2	39.5	41.3	39.2	39.8

TABLE 3.—COMPARISON OF REACTIONS OF LARVAE TO 40° C. AND RELATIVE HUMIDITIES OF 20 TO 80%

Relative humidity	Average longevity	Weight loss
%	days	%
20	1.1	48
40	1.4	49
50	1.4	47
60	2.5	49
70	2.6	42
80	4.6	40

TABLE 4.—SUMMARIZED ANALYSIS OF DESICCATION OF 60 NAKED SAWFLY LARVAE AT 35° C. AND RELATIVE HUMIDITIES OF 10 TO 60%

——	Total	Water	Dry matter
Initial weight	927 mg.	500 mg. (54.0%)	427 mg. (46.0%)
Death weight	501 mg.	195 mg. (38.5%)	306 mg. (61.5%)
Percentage loss	46.0%	61.0%	35.3%

matter content, although the total weight will have been reduced. Two similar specimens may undergo vastly different moisture treatments, and end up with similar proportions of moisture and dry matter. Many other possibilities exist, even in the relatively simple cases of non-feeding stages. It is therefore desirable to know as much of the previous moisture history of the material as possible, not only at the beginning of the experiment but often before it as well. If such information is not available, or if it shows that there is considerable variation in the material, then it should be realized that any variation present will be reflected in the results. The experiments reported here will serve as an example. The experimental material was judged to be fairly uniform in most respects, but there were large differences in size as well as some differences in amount and proportion of moisture and dry matter. As it was not feasible to substantially reduce this variation by rigid selection of material, some accuracy was sacrificed. The variations in the data obtained are considered to be too great for precise mathematical analysis of those data, but sufficiently small as not to affect the general conclusions.

MORTALITY IN STUBS EXPOSED TO 40° C. AND 0% R. H.

In order to test the resistance to desiccation of *Cephus cinctus* throughout the entire period that it spends in the stub, collections of stubs were made periodically and exposed to a set of standard drying conditions. In order to reduce the time factor to a workable level, all stubs were exposed to 40° C. and 0% R. H. within a few hours of being brought in from the field. It should be remembered that all stages were non-feeding. The unit sample was 25 stubs, with a few extras being included to allow for mortality

from causes other than desiccation, such as disease and parasitism. The stubs were split open at the end of the exposure period and the mortality of larvae, pupae or adults noted. Collections were made from April 30, 1943, to June 15, 1944, thus including 2 seasons of spring development and 1 of the period spent in diapause from harvest-time to freeze-up. All collections were made from the same field or its adjoining counterpart in a two-year wheat-summerfallow rotation. Table 5 compares the mortality of developing larvae, pupae and adults in the springs of 1943 and 1944, while Table 6 lists the mortality of diapause larvae in the fall of 1943.

Spring-collected larvae varied considerably in their resistance to desiccation in the 2 years. It was impossible in many cases to distinguish between prepupal and non-prepupal larvae after death, and of course it was impossible to know what proportion of each had been present in the sample before drying. Nevertheless, the differentiation was made in sufficient cases that it soon became apparent that prepupal larvae were the more susceptible of the two. This is supported by the 1944 data in Table 5 and to some extent by the 1943 data, which, however, contain too few samples for adequate analysis. A further decrease in resistance to desiccation very definitely takes place during the pupal stage. In fact, it appears to be a fairly uniform, progressive decrease, beginning with the preplpa and proceeding to the adult. Table 5 contains only one column of values for adult mortality, and these are for adults which had not yet left the stubs. Free-flying adults were all killed in 2 or 3 hours at 40° C. and 0% R. H. Not only did adults die more quickly than pupae, but they afterwards dried to a state of brittleness in a shorter time than pupae, while pupae became brittle more rapidly after death than did larvae. In fact, there seems to be the same order of resistance or susceptibility to drying after death as before.

Table 6, dealing with fall-collected larvae, shows that there was a progressive increase in resistance to desiccation during August, followed by an approximately equal decrease during September. No explanation is offered for this fluctuation, or for the even greater change that took place between October 7, 1943, and April 24, 1944 (cf. Table 5). There was no uniformity of results among larvae collected at different times of the year, or in similar seasons of 2 different years. The only safe comparison seems to be with later stages, which were progressively less resistant.

The object of this latter group of tests was to discover at what stage and season the species was most susceptible to desiccation, so that such information could be taken into consideration in making control recommendations. The experimental results clearly indicate that susceptibility increased progressively during the spring as development proceeded from the prepupa to the adult. While the results obtained with larvae exhibit considerable variation, they show a rather high degree of resistance to desiccation at temperatures up to 40° C. Higher temperatures would of course reduce the time necessary to produce lethal desiccation and in addition could become a lethal factor independently of moisture. Nevertheless, the larval stage is the most resistant stage present during a period of about 10 months, from mid-August to mid-June.

TABLE 5.—PERCENTAGE MORTALITY OF SPRING-COLLECTED LARVAE, PUPAE AND ADULTS EXPOSED TO 40° C. AND 0% R. H., 1943 AND 1944

Exposure (days)	Percentage mortality																				
	1943												1944								
	Larvae			Pupae									Larvae					Pupae			Adults
	April	May		May		June							April	May				May	June		June
	30	14	18	27	29	2	4	9	11	16	18	22	24	2	6	12	17	31	7	15	15
1	—	—	20	—	—	—	2	2	34	46	80	73	0	0	0	0	0	0	0	20	0
2	4	—	56	9	10	20	15	77	100	98	100	100	0	0	0	4	0	20	20	80	55
3	52	48	78	47	91	25	—	93	100	100	100	100	0	0	0	0	0	65	75	100	100
4	44	—	—	—	94	—	100	100	—	—	—	—	0	5	0	0	25	—	90	100	100
5	56	92	—	—	100	100	—	—	—	—	—	—	0	0	4	4	10	95	100	100	100
6	80	—	—	—	—	100	—	—	—	—	—	—	4	5	0	0	65	100	100	—	—
7	—	96	—	—	—	—	—	—	—	—	—	—	4	0	0	0	40	100	100	—	—
8	—	—	—	—	—	—	—	—	—	—	—	—	32	0	36	0	70	100	—	—	—
9	—	—	—	—	—	—	—	—	—	—	—	—	16	0	20	8	75	100	—	—	—
10	—	—	—	—	—	—	—	—	—	—	—	—	44	—	72	0	95	—	—	—	—
11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	76	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	80	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	100	—	—	—	—	—	—

TABLE 6.—PERCENTAGE MORTALITY OF FALL-COLLECTED DIAPAUSE LARVAE EXPOSED TO 40° C. AND 0% R. H.

Exposure (days)	Percentage mortality						
	August			September			October
	10	17	28	4	10	28	7
1	4	4	0	0	0	—	—
2	12	0	0	0	0	16	8
3	48	44	4	8	4	48	24
4	46	78	8	12	32	82	60
5	88	96	12	32	60	86	90
6	97	96	28	52	76	98	100
7	—	88	76	80	96	—	100
8	—	—	52	96	100	—	100
9	—	—	96	100	100	—	100

SUMMARY

At 30° C., and relative humidities of 0 to 50%, naked *Cephus cinctus* larvae lost weight very rapidly at first, then more slowly, losing more than 40% of their original weight before drying from desiccation.

Longevity decreased and rate of weight loss increased as the relative humidity was reduced from 50 to 0%.

At 35° C. (0 to 60% R. H.) and at 40° C. (0 to 80% R. H.) the results were the same as at 30°, except that the time factor was reduced as the temperature was raised. At all temperature and moisture conditions investigated, larvae died only after losing more than 40% of their original weight.

Temperatures up to 40° C. did not in themselves have any lethal effect.

The lack of covering of the larvae, which were removed from the protection of their stubs and cocoons, had no lethal effect in itself.

Death occurred only as a result of desiccation.

During desiccation the amounts of both moisture and dry matter are reduced; but whereas the percentage of moisture decreases, the percentage of dry matter increases.

Freshly collected material exposed in the stubs to a set of standard drying conditions showed considerable seasonal differences in resistance during the 10-month period that the species spends in the stub. Larvae were most resistant to desiccation, although they exhibited considerable variation. Prepupae were less resistant than non-prepupal larvae, and as development proceeded from prepupa to adult the resistance steadily decreased.

Dead specimens showed the same general trend as living specimens in regard to relative susceptibility or resistance to desiccation.

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REFERENCES

1. LUDWIG, D. The effect of different relative humidities on survival and metamorphosis of the Japanese bettle (*Popillia japonica* Newman). Physiol. Zool. 10 : 171. 1937.
2. MANSON, G. F. A preliminary report on the effect of rainfall on emergence of the wheat stem sawfly (*Cephus cinctus* Nort.). Quebec Soc. for Protection of Plants. 25-26th Rep. for 1932-34, pp. 101-106. 1934.

MOISTURE RELATIONSHIPS OF THE WHEAT STEM SAWFLY (*CEPHUS CINCTUS* NORT.)

II. SOME EFFECTS OF CONTACT MOISTURE[1]

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A previous paper (Salt 1) has dealt with some of the effects of desiccation at high temperatures on larvae, pupae and adults of the wheat stem sawfly. It was shown that while larvae in good condition had a moisture content of roughly 52 to 58%, they lost more than 40% of their original weight before dying from desiccation, at which time their moisture content was less than 40% of their body weight. One of the control measures used against this pest is a shallow tillage operation, designed to remove the "stubs" from the soil and leave them lying on the surface of the ground, exposed to desiccation, high temperature, predators and possibly other unfavourable factors. Desiccation, in combination with high temperature, appears to be the most important of these factors. The drying of larvae in exposed stubs in the field is an intermittent process in most cases, as periods of hot, dry weather are interspersed with cooler, moister weather which may be accompanied by occasional rain. It is with the effects of moistening or wetting the stubs and larvae that this paper is concerned.

In order to find out whether larvae actually gained in weight when placed in contact with moisture, they were removed from the stubs and placed individually between layers of damp cellucotton. Larvae were weighed periodically to the closest tenth-milligram. In this way, the variation in weight of an individual could be followed, but its moisture content remained unknown until the end of the experiment. In other experiments, stubs were exposed to contact moisture over a period of days, the moisture content of samples being taken at specified intervals. A check sample, not exposed to contact moisture, was also taken. The moisture content was arbitrarily determined by oven-drying at 95° to 100° C. for 24 hours, by which time the weight had become constant. A variation of the second group of experiments consisted in comparing the daily mortality in soaked and unsoaked stubs when exposed to 40° C. and 0% R. H. This experiment is summarized in Table 1. The stubs received identical treatment except that the "wet" stubs were submerged in tap water for 1 minute, drained and kept in a closed glass jar for 4 days.

After 4 days' contact with moisture the "wet" larvae increased in moisture content from 51.3 to 55.3%, a significant change. While this fact is of considerable importance in the problem under consideration, Table 1 contains other interesting data. Mortality was delayed by the moisture treatment, yet the last column shows that the 4% increase in moisture content which was gained in 4 days as a result of this treatment, was lost by the end of 1 day at 40° C. and 0% R. H. If the change in moisture content is all that is involved, then the mortality of the wet series

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TABLE 1.—COMPARISON OF DAILY MORTALITY, AND PERCENTAGE MOISTURE CONTENT OF SURVIVORS, OF LARVAE IN "WET" AND "DRY" STUBS EXPOSED TO 40° C. AND 0% R. H.

No. days exposure	"Dry" series		"Wet" series	
	Mortality	Moisture content of survivors	Mortality	Moisture content of survivors
	%	%	%	%
0	0	51.3	0	55.3
1	32	42.8	4	51.7
2	92	—	0	50.7
3	96	—	4	50.7
4	100	—	28	48.7
5	—	—	24	50.2
6	—	—	36	51.2
7	—	—	36	49.5
8	—	—	52	48.3
9	—	—	52	49.7
10	—	—	92	—
11	—	—	92	—

should equal that of the dry series for the previous day. This is not the case, but is an indication that the soaking not only raised the moisture content, a change that was readily reversible, but also caused a more permanent physiological change. No attempt is made here to explain this change, and for the purposes of this paper the main point in Table 1 is the increase in moisture content of larvae from 51.3% to 55.3% when exposed to a moderate amount of contact moisture for 4 days.

Further proof that larvae increase their moisture content when the stubs are in contact with moisture was obtained incidentally from other experiments. In one, 650 stubs with an initial moisture content of 51.6% (on the basis of a sample) were submerged in tap water for 1 minute, drained, and kept in a closed glass jar for 9 days. At the end of this time, a sample of 25 larvae had a moisture content of 58.4%. In another instance, 200 stubs were removed from storage in a root cellar in November 1944 and placed in a desiccator at 25° C. and 0% R. H. The initial moisture content of a sample of 10 larvae was 56.3%, a figure which was gradually reduced by desiccation until on January 3, 1945, the moisture content of a sample was 50.5%. On this date, the stubs were placed upright in a tin, covered with sifted loam of 14.0% moisture content, and the lid sealed with adhesive tape. Samples were removed periodically and the moisture content of 10 larvae was determined. Toward the end of the experiment pupae began to appear in the stubs. These were discarded, so that the figures listed in Table 2 represent the moisture content of 10 larvae. The soil in which the stubs were placed was sifted through a 20-gauge wire screen, so it was far from wet. Yet it was sufficiently damp to supply contact moisture to the stubs and the larvae within them. The moisture content of the larvae increased definitely, though somewhat irregularly. Nevertheless it amounted to 7 or 8% and supports the conclusion that the moisture content of larvae can increase under such conditions.

TABLE 2.—PERCENTAGE MOISTURE CONTENT OF LARVAE EXPOSED (IN STUBS) IN SOIL OF 14.0% MOISTURE CONTENT, AT 25° C.

No. days exposure	No. prepupae in sample of 10 larvae	Moisture content	No. days exposure	No. prepupae in sample of 10 larvae	Moisture content
		%			%
0	0	50.5	17	2	57.6
2	1	53.3	20	1	58.1
5	1	52.8	25	0	56.8
8	0	56.1	30	1	59.3
10	1	55.0	35	0	58.9
12	1	55.7			

The percentage moisture content of an insect, however, is the ratio of moisture to total weight, the latter being the sum of moisture plus dry matter. The percentage of moisture can therefore increase in any of 3 ways, (1) an increase in actual amount of moisture, (2) a decrease in actual amount of dry matter, and (3) a proportionate increase in moisture. In the above experiments there probably was some loss in dry matter, especially at the longer exposures. It would hardly be sufficient, however, to account for the relatively large increases in percentage moisture content. Further experiments showed that moisture is actually taken up by the insect, so that the increase in percentage moisture content values can be interpreted as an actual increase in the amount of moisture.

The first experiment using larvae removed from the stubs was an extreme case. Seven diapause larvae which had been severely desiccated in another experiment were weighed and placed between layers of damp cellucotton at 22° C. Although the exact moisture content of these seven specimens was of course unobtainable, yet on the basis of other specimens in the desiccation experiment it is certain that they had a moisture content of less than 45%. The treatment of each larva before the experiment and its reaction to the contact moisture are given in Table 3.

TABLE 3.—CHANGE IN WEIGHT OF PARTIALLY DESICCATED DIAPAUSE LARVAE WHEN PLACED IN WET CELLUCOTTON AT 22° C.

No. days 40° C., 0% R. H.	Initial		Weight at				Condition at 22 d.
	Condition	Weight	1 d.	4 d.	14 d.	22 d.	
		mg.	mg.	mg.	mg.	mg.	
5	Feeble	8.0	8.0	8.0	8.8	8.8	Active
5	Feeble	4.3	4.5	4.5	6.0	(moulded)	Dead
6	Feeble	6.6	6.8	6.7	7.6	7.6	Active
4	Very feeble	6.8	7.0	7.1	8.5	10.0	Active
4	Very feeble	3.2	3.2	3.1	4.2	4.7	Very feeble
5	Sluggish	9.6	9.8	9.6	10.5	10.6	Active
5	Sluggish	6.0	6.0	5.9	6.8	6.9	Active
Percentage increase in weight			1.6	0.0	17.2	20.9	—

All of the larvae had gained weight by the end of the experiment and 5 of them returned to an apparently healthy state. The increase in weight started several days after the beginning of the experiment but the weighings were too infrequent to show any detail. A more careful experiment was therefore started, using 20 diapause larvae. These were kept separately between layers of damp cellucotton, which was replaced weekly. No trouble was experienced from mould. The larvae were selected for size, forming a group of 10 large larvae (average weight 9.9 mg., range 8.0 to 14.1 mg.) and 10 small larvae (average weight 3.5 mg., range 2.7 to 4.1 mg.). The large larvae were actually much closer to an average weight (8 to 10 mg.) than the small ones.

The use of 2 size groups was a result of numerous casual observations which had indicated that their reactions to many factors were distinctly different. The size of *C. cinctus* larvae is presumably dependent on physiological factors (chiefly nutrition, in turn dependent on that of the host plants) as well as genetic factors. On size depend the ratios, for example, of surface area and tracheal area to body weight, both of which are probably important in any consideration of moisture intake or loss. The rate of post-diapause development bears in this species a direct relationship to size.

A sample of 11 larvae from the same stock as the experimentals had a moisture content of 42.7%. Like those in Table 3 these larvae were severely desiccated and were in diapause.

Figures 1A and 1B show the increase in weight of the larvae during the experiment. Three larvae in each series were removed on the 15th day for a moisture content determination. Each of these was of average behaviour from the standpoint of weight increase; their moisture contents will be discussed later. One larva in each series died before the 15th day—a large one on the 40th day after a phenomenal weight increase, and a small one on the 24th day after virtually no increase. All of the remaining 6 large larvae, and 3 out of 6 small larvae, were alive and apparently healthy when the experiment ended on the 79th day. It should be noted that the 3 small larvae which survived had more moderate weight increases than those which died. It would have been interesting to follow all of these larvae up to the time of their death, but their moisture content was desired and on the 79th day they were weighed and placed in the electric oven.

In the first 9 days some larvae lost a small amount of weight, although this is not shown in the figures. The small larvae required a few days to register an increase, while a few large ones began to gain immediately. Except in one case (the fatal one) and to some extent one other, the large larvae were fairly uniform in their reaction to contact moisture. The small larvae were more irregular both as individuals and as a group. Temporary losses or failure to gain were more common with them. It would be difficult to choose an average or normal curve for small larvae, while this would be relatively simple for large larvae.

The 4 whose weight increases were notably greater than those of the others, all died before the end of the experiment. Whether they died as a result of their remarkable absorption of moisture or whether the absorption

followed some physiological disturbance is not known. At any rate, the individuals having the flatter weight-increase curves were more healthy and may be considered more normal than the others, since the duration of treatment is admittedly extreme.

It is apparent then that sawfly larvae can absorb contact moisture, the word "absorb" being used in a broad sense. While the possibility of the larvae drinking moisture, or eating cellucotton, was not entirely ruled out

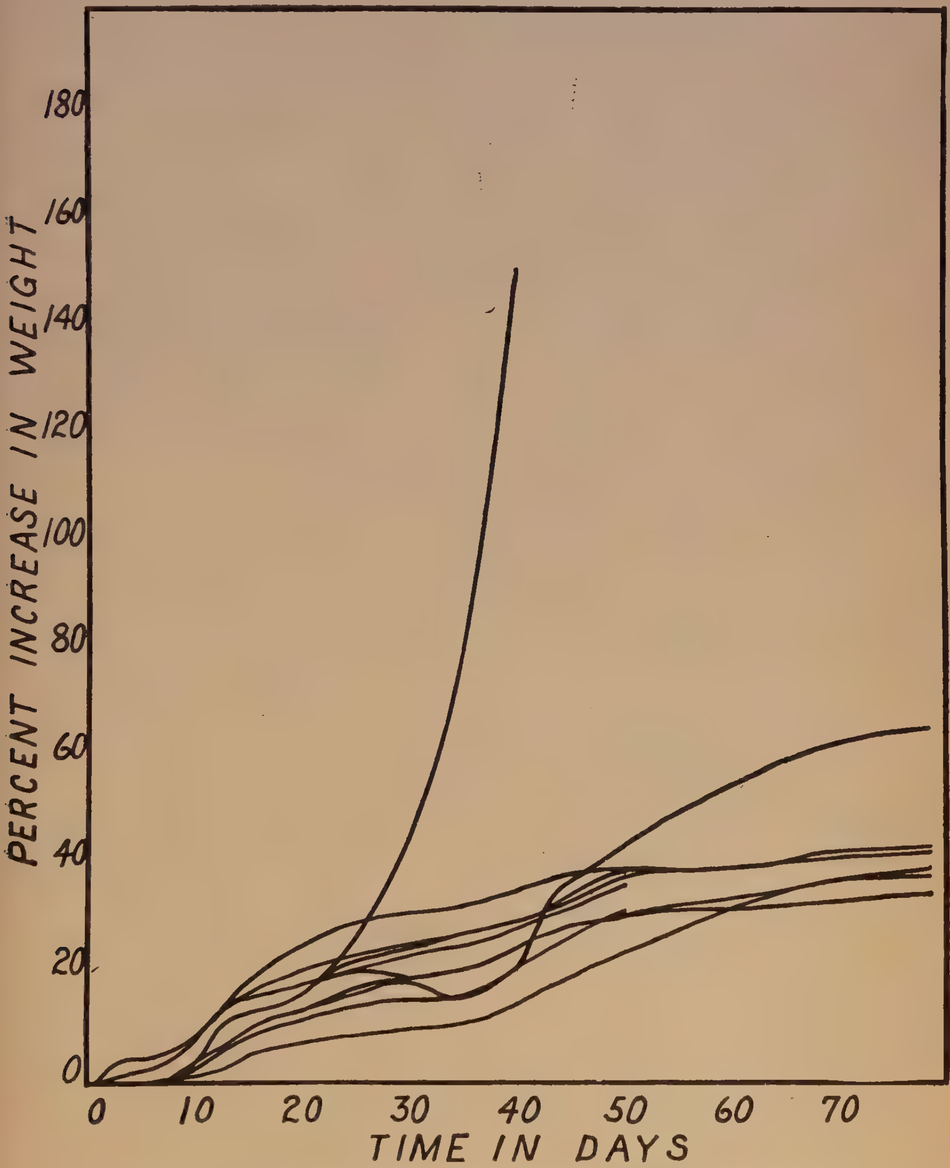

FIGURE 1A. Increase in weight of 10 large, naked, diapause *Cephus cinctus* larvae exposed to contact moisture at 22° C.

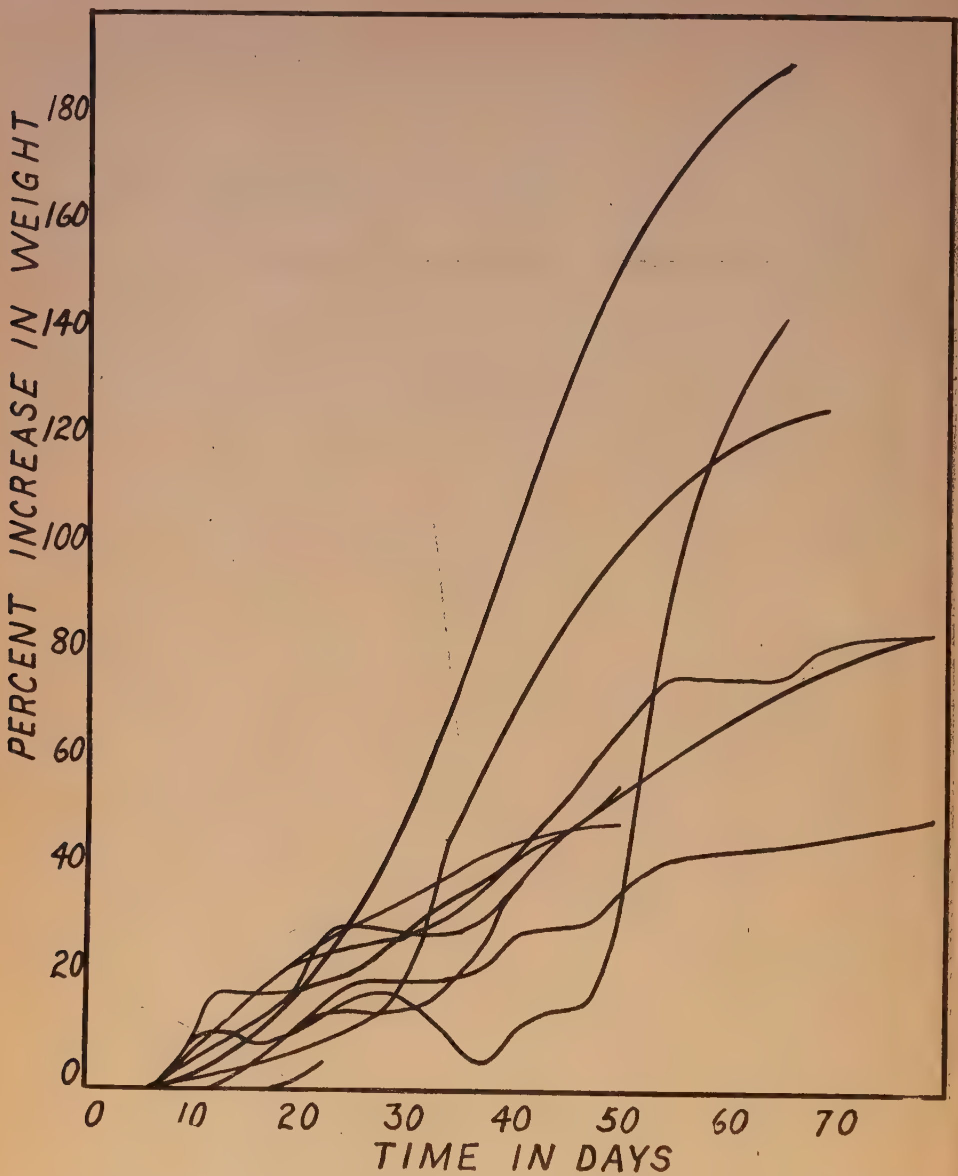

FIGURE 1B. Increase in weight of 10 small, naked, diapause *Cephus cinctus* larvae exposed to contact moisture at 22° C.

in this experiment, it seems very unlikely that this occurred. The larvae at this stage are in a normally overwintering, diapause condition and have completed feeding some time before forming their cocoons. The ingestion of solids would be detrimental to them at this time, although watery liquids might not be harmful.

Temporary loss of weight occurred in some specimens. This is considered to indicate that the utilization of solids during metabolism was greater than the absorption of moisture. Minor losses of weight may have

been due to the experimental error in weighing, which amounted to ± 0.1 mg., or about 1% in large larvae and 3% in small larvae. One small larva, however, lost weight far in excess of the experimental error, and then recovered, to gain 144% before its death on the 75th day.

As previously mentioned, 3 larvae in each series were oven-dried on the 15th day of exposure. The oven-dry weight was taken to be the weight of dry matter, and the loss in weight during drying was considered to be moisture. In addition, the dry matter and moisture content at the start of the experiment was calculated on the basis of the figures for the controls, namely, 57.3% dry matter and 42.7% moisture. Table 4 lists the recorded and calculated weights, while Table 5 contains an analysis of them.

TABLE 4.—WEIGHTS OF SAMPLE LARGE AND SMALL LARVAE AFTER 0 AND 50 DAYS' EXPOSURE TO CONTACT MOISTURE AT 22° C.

No.	Initial weight			Weight at 50 days		
	Total	Calculated dry matter	Calculated moisture	Total	Dry matter	Moisture
	mg.	mg.	mg.	mg.	mg.	mg.
L4	8.0	4.6	3.4	11.0	4.0	7.0
L5	9.3	5.3	4.0	12.3	4.1	8.2
L8	9.7	5.6	4.1	13.5	4.9	8.6
S3	3.5	2.0	1.5	5.5	1.4	4.1
S4	3.5	2.0	1.5	5.2	1.5	3.7
S9	3.7	2.1	1.6	5.8	1.6	4.2
Total large	27.0	15.5	11.5	36.8	13.0	23.8
Total small	10.7	6.1	4.6	16.5	4.5	12.0

TABLE 5.—COMPARISON OF REACTIONS OF SAMPLE LARGE AND SMALL LARVAE TO 50 DAYS' EXPOSURE TO CONTACT MOISTURE AT 22° C.

Size	%		% Change			Ratios of % change		
	Dry matter	Moisture	Total weight	Dry matter	Moisture	Moisture / Total	Dry matter / Total	Moisture / Dry matter
Large	35	65	+36	−16	+107	2.97	0.44	6.7
Small	27	73	+54	−26	+161	2.98	0.48	6.2

Percentage figures in Table 5 are given to the nearest integer because of the experimental error in weighing.

In each series the moisture increase was considerably greater than the dry matter decrease, thereby producing a substantial net gain in weight. Comparing the 2 series it is seen that the small larvae gained roughly 50% more moisture and lost about 60% more dry matter than the large larvae (on the basis of body weight in each case). The relative changes, however, were similar in each size group, as shown in the last 3 columns of Table 5. This indicates that any difference in the 2 sets of figures for percentage of weight change is one of extent rather than of composition.

Even though these sample larvae were selected for average weight increase during the first 50 days of the experiment, the small larvae appear to be more extreme in their reactions to contact moisture than the larger ones. This is apparent also in Figures 1A and 1B. Taking into consideration not only these and other experimental studies on sawfly larvae but also field observations, it should perhaps be re-stated here that the large larvae in the above experiment are somewhat more representative of a normal population than the smaller ones. The size and apparent state of health of larvae varies considerably in nature, depending chiefly on the condition of the host plants during larval development, which in turn is dependent on a complexity of factors.

After removing 3 samples at 50 days, each group contained 6 larvae. All of the 6 large larvae lived until the end of the experiment at 79 days. Three small larvae died between 65 and 79 days, and each of these was an extreme case. In Table 6 the data for these 3 are treated separately from the 3 larvae which reacted more normally.

TABLE 6.—COMPARISON OF REACTIONS OF LARGE AND SMALL LARVAE TO CONTACT MOISTURE AT 22° C. FOR 65 TO 79 DAYS

Size	No. days exposure	%			% Change		Ratios of % change		
		Dry matter	Moisture	Total weight	Dry matter	Moisture	Moisture / Total	Dry matter / Total	Moisture / Dry matter
Large	79	28	72	+ 44	−31	+144	3.27	0.70	4.6
Small (average)	79	20	80	+ 74	−39	+221	2.86	0.53	5.7
Small (extreme)	65 to 79	15	85	+155	−31	+400	2.58	0.20	12.9

In the period after 50 days' exposure, larvae continued to gain moisture and lose dry matter but the proportions were not similar in the 2 groups as they had been at 50 days. The 3 small larvae which died at 65 to 79 days gained a much greater proportion of moisture. Both large and small larvae which survived the full period of the experiment used up more dry matter per unit increase in either total weight or moisture than at 50 days.

DISCUSSION

The ability to absorb moisture is of great importance to sawfly larvae in their natural environment, for it has already been shown that they lose moisture with comparative ease (Salt 1). As one control measure is aimed at exposing the larvae to lethal desiccation during hot, dry weather, the ability of the larvae to absorb moisture if the stubs become dampened by rains counteracts the desiccation if it has not already proved fatal. The experimental work so far has included only desiccation at temperatures up to 40° C. and the absorption of moisture chiefly at 22° C. Further study at temperatures closer to the upper lethal limit would undoubtedly prove of practical importance and theoretical interest, for in the desiccation

studies previously reported temperature was considered of practical importance only insofar as it affected desiccation. The two factors are of course inseparably linked, along with a third factor, time.

SUMMARY

Diapause larvae of *Cephus cinctus* Nort. readily absorbed contact moisture, often in large amounts, at room temperature. Some dry matter was lost as a result of physical activity and general metabolism.

While absorbing contact moisture and losing small amounts of dry matter the wet weight increased, the percentage moisture content increased and the percentage of dry matter decreased. With three factors changing, the picture is best expressed by the values for percentage change of total weight, moisture and dry matter.

Small larvae were erratic and in many cases extreme in their absorption of contact moisture. Large and average-sized larvae reacted more moderately. As most of the larvae used in these experiments were rather severely desiccated to begin with, the changes listed may be considered maxima.

REFERENCE

1. Salt, R. W. Moisture relationships of the wheat stem sawfly (*Cephus cinctus* Nort.). 1. Some effects of desiccation. Sci. Agr. 26 : 622-630. 1946.

RESPONSE OF BURLEY TOBACCO VARIETIES TO IONIC FORMS OF NITROGEN[1]

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Knowledge of hereditary variation in plant nutrition is at present very limited. Hoffer (6) found that 13 inbred lines of corn and 2 hybrids gave differential growth on clay and loam soils. Five barley varieties differed significantly in their response to 3 levels of N, P, and K in all combinations, according to Gregory and Crowther (2). Smith (14) reports finding a differential response between inbred lines of corn on low phosphorus levels and, to a lesser degree, on low nitrogen. The findings of Lyness (10) with inbred strains and hybrids of corn on different levels of phosphorus and nitrogen were in close agreement with those of Smith. Stringfield and Salter (15) and Lamb and Salter (8) (9) conducted a corn-oats-wheat rotation on 4 levels of fertility in which corn varieties and hybrids showed a significant 'variety $\times$ level of fertility' interaction 2 years out of 5. Wheat gave significant interaction with fertility levels for 5 years but oats did not. Harvey (4) reports a differential response by corn strains and hybrids to ammonium and nitrate nitrogen and a differential response by tomato strains of 2 species to low levels of N, P, and K as compared to full nutrient solutions.

This paper deals with the response of two burley varieties of tobacco, namely, Harrow Velvet and Kelley, to nitrate and ammonium nitrogen.

MATERIALS AND PROCEDURE

The seeds of the 2 tobacco varieties were set out on July 15, 1941, on moist filter paper to germinate and, on July 25, the seedlings were planted in Nepean sandstone in 3 in. pots. All plants were supplied with a uniform nutrient solution containing no ammonium nitrogen. This solution was made from $Ca(NO_3)_2$, KH_2PO_4, and $MgSO_4$ in the ratio 8 : 2 : 5, with minor elements added. On September 22, 1941, the plants were potted in 3-gallon pots containing 45 pounds Nepean sandstone, 1 plant per pot. Water only was supplied the plants until September 29, when it was replaced by nutrient solutions which were supplied by the constant flow drip method. Four nutrient solutions were used. These ranged from 100% NO_3^-, decreasing NO_3^- nitrogen and increasing NH_4^+ nitrogen in increments of $\frac{1}{3}$ of the total nitrogen to 100% NH_3^+ nitrogen. The concentrations of N, Ca, and K were constant in all treatments. S was supplied at a concentration of 45, 93, 140, and 189 p.p.m. and P at a concentration of 196, 228, 265, and 253 p.p.m. in treatments 1, 2, 3, and 4, respectively. The minor elements B, Mn, and Zn were supplied at the rate of 0.5 p.p.m. and Fe at the rate of 3.0 p.p.m. in all treatments.

The plants were harvested 3 months after planting in 3-gallon pots. Fresh weights were taken of 4 fractions of the tissue: the tops, consisting of the portion of the plants usually removed by "topping"; the top leaves;

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the bottom leaves; and the stalks. These fractions were diced, thoroughly mixed, and aliquots weighed out for the dry-weight determinations and for chemical analyses of all except the first-named fraction.

RESULTS

The growth data are contained in Table 1. The % dry weight per plant is a calculated value since the actual % dry weight determinations were based on the 4 stated fractions of the tissue. Additionally, the average fresh weights are presented graphically in Figure 1.

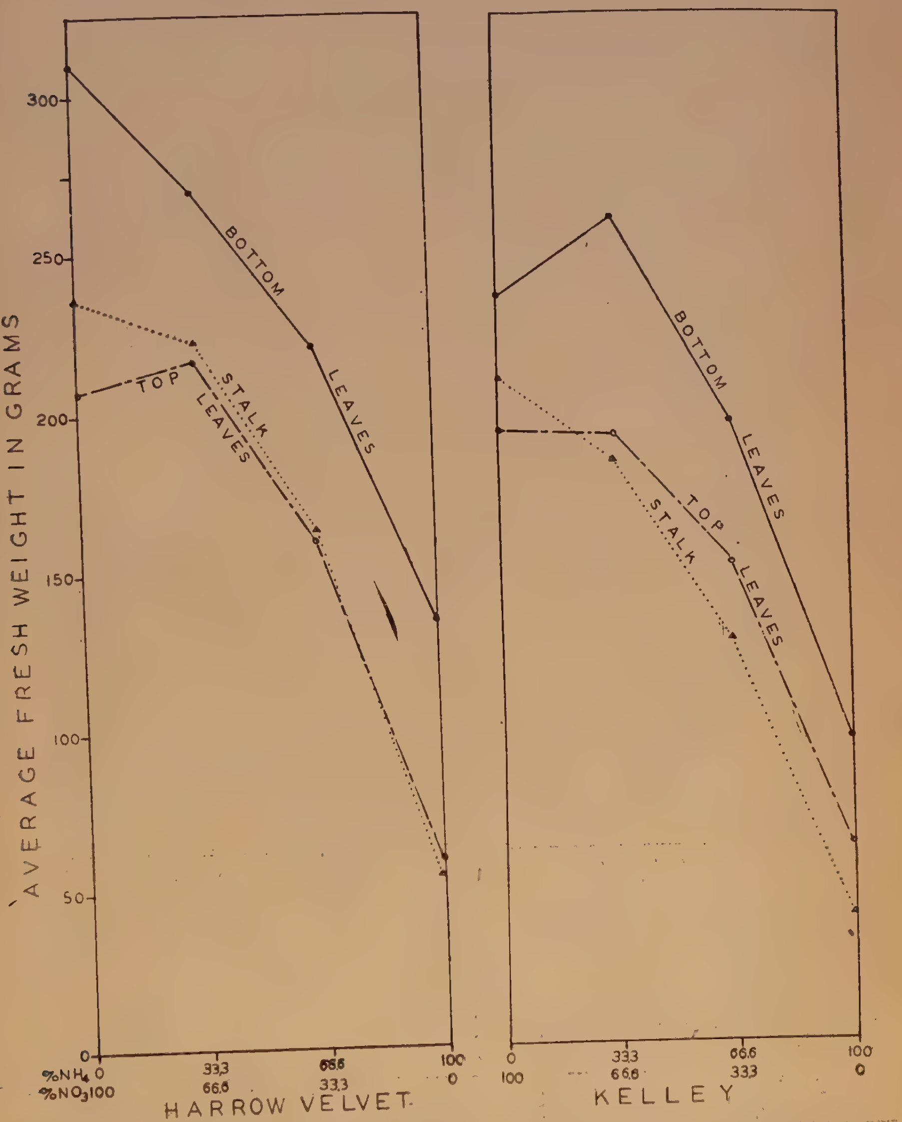

FIGURE 1. Growth response of tobacco varieties to ionic forms of nitrogen.

A summary of the analysis of variance based on total fresh weight data is presented in Table 2. The mean square for varieties is above the 1% level, as measured by its P value, and the value given in Table 10.2 of Snedecor's "Statistical Methods" 1938. This is true also of the mean square for solutions. Therefore, both varieties and solutions were sources of significant variation. The 'varieties × solutions' mean square lies below the level of significance (below the 5% level). Thus, the differential varietal response to solutions was not significant under the conditions of this test.

The mean fresh weights of both varieties on the 4 nutrient solutions are presented in Table 3. The difference necessary for significance = 51.8 (P = .05). The mean yield on each of solutions 1 and 2 is significantly greater than that on either solution 3 or 4, while no significance can be assigned to the difference between solutions 1 and 2. From this it is apparent that the plants of each variety differed in their response to nitrate versus ammonium nitrogen. A concentration of ⅓-ammonium nitrogen in the nutrient solution did not have a significant effect on yield as compared to all-nitrate nitrogen; but, above this level, a progressive increase in the proportion of ammonium nitrogen resulted in a progressive decrease in yield.

Table 1.—Yield in grams of varieties grown with constant nitrogen supply but various proportions of nitrate and ammonium ions

Treatment No.	Ionic proportions		Variety	Average fresh weight per plant					Ave. dry weight per plant
	NO_3^-	NH_4^+		Top	Top leaves	Bottom leaves	Stalk	Total	
1	All	0	Harrow Velvet	15.8	206.9	308.7	235.5	766.9	68.29
			Kelley	82.6	193.4	236.0	210.2	722.2	61.35
2	⅔	⅓	Harrow Velvet	129.0	217.4	270.2	222.7	839.3	75.52
			Kelley	109.1	191.9	260.7	184.2	745.9	63.28
3	⅓	⅔	Harrow Velvet	80.2	160.0	222.9	163.0	626.1	62.67
			Kelley	91.7	151.9	197.4	127.8	568.8	47.41
4	0	All	Harrow Velvet	11.0	68.0	130.2	52.8	262.0	22.40
			Kelley	42.8	61.4	96.8	39.2	240.2	18.17

Table 2.—Analysis of variance based on total fresh weight of plants

Source of variation	Degrees of freedom	Mean square	Calculated F values	Significant F values	
				5%	1%
Varieties	1	44,199.84	11.20**	4.08	7.31
Solutions	3	714,233.12	180.92**	2.84	4.31
Varieties × Solutions	3	5,274.10	1.34	2.84	4.31
Error	40	3,947.83	—	—	—
Total	47				

** Highly significant.

TABLE 3.—MEAN TOTAL FRESH WEIGHT IN GRAMS OF BOTH VARIETIES

Solution No.	Ionic proportions		Mean fresh weight
	NO_3^-	NH_4^+	
1	All	0	744.7*
2	$\frac{2}{3}$	$\frac{1}{3}$	790.3
3	$\frac{1}{3}$	$\frac{2}{3}$	598.1
4	0	All	251.0

* Difference necessary for significance ($P = 0.05$) = 51.8.

The plants grown on high ammonium manifested symptoms of magnesium deficiency (sand drown) and a brown discoloration of the roots.

CHEMICAL ANALYTICAL RESULTS

The results of the analyses of the plants for N, P, K, Ca, Mg, and S, reported as percentage of the dry weight of the samples of ground tissue, are the averages of closely-agreeing duplicate analyses. The methods used in the analyses were the official methods of the A.O.A.C. (11) with one exception—total nitrogen was determined by the method of Pucher *et al.* (12).

The data representing the concentration of the 6 elements studied are given in Table 4 and are presented for each of the 6 elements individually in graphic form in Figures 2 to 7.

The effect of the ionic forms of nitrogen in the nutrient solution on the content of nitrogen in the plant tissues is shown in Figure 2. In general, the curves show an acceleration of accumulation of nitrogen in all 3 fractions of the tissue with increase in ammonium nitrogen and decrease in nitrate nitrogen in the nutrient solution. The curves deviate downward only slightly for the top leaves of both varieties and the stalk of Harrow Velvet at the point where the NO_3^- : NH_4^+ ratio was 2 : 1 (treatment 2). Both varieties accumulated nitrogen from NO_3^- at approximately the same rate, but Kelley accumulated nitrogen in both leaf tissues and in the stalk tissue at a greater rate than did Harrow Velvet at the NH_4^+ end of the solution. This indicates that the 2 varieties differ in their capacity for selective utilization of ionic forms of nitrogen; however, the varietal difference in this regard was not statistically significant.

The accumulation of phosphorus in the top leaves (Figure 3) was associated with increasing NH_4^+ and decreasing NO_3^- in the nutrient supply in treatment 1, 2, and 3 but was depressed slightly at 100% NH_4^+ nitrogen. The accumulation of phosphorus in the bottom leaves was relatively unaffected by variation in the ionic proportions in the substrate, increasing only slightly from treatments 1 to 3, and decreasing at 100% NH_4^+ nitrogen. In the stalk, the content of phosphorus increased markedly from treatments 1 to 2, then slightly to the NH_4^+ end of the solution. The curves for both varieties are very similar.

Figure 4 shows that potassium accumulated in the stalk tissue with decreasing NO_3^- and increasing NH_4^+ in the substrate. However, in both top leaves and bottom leaves of both varieties, the potassium content

TABLE 4.—A SUMMARY OF THE MINERAL ANALYSES OF TOP LEAVES, BOTTOM LEAVES, AND STALK TISSUE EXPRESSED AS % OF DRY WEIGHT

Treatment No.	Ionic proportions		Variety	Top Leaves						Bottom Leaves						Stalk					
	NO_3^-	NH_4^+		N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
1	All	0	Harrow Velvet	5.19	0.59	5.55	3.21	0.39	0.75	4.19	0.54	6.65	3.42	0.62	0.56	2.26	0.34	5.21	1.43	0.11	0.22
			Kelley	5.34	0.54	5.59	3.47	0.38	0.71	4.23	0.54	6.56	3.92	0.66	0.47	2.42	0.32	5.34	1.49	0.14	0.23
2	⅔	⅓	Harrow Velvet	5.14	1.02	6.23	2.50	0.36	1.26	4.32	0.56	6.91	3.06	0.45	1.30	2.02	0.54	5.13	1.29	0.13	0.27
			Kelley	5.25	0.88	6.03	2.85	0.34	1.08	4.54	0.55	7.15	2.77	0.56	1.31	2.65	0.58	5.27	1.32	0.13	0.31
3	⅓	⅔	Harrow Velvet	5.36	0.92	6.16	2.12	0.27	1.07	4.58	0.63	5.77	2.33	0.36	1.50	2.17	0.61	4.25	0.87	0.09	0.41
			Kelley	6.03	1.09	5.50	1.93	0.24	1.11	5.75	0.54	5.75	2.41	0.30	1.47	3.06	0.61	4.01	1.01	0.11	0.24
4	0	All	Harrow Velvet	6.17	0.94	5.04	1.82	0.28	0.63	5.10	0.56	5.30	1.61	0.33	1.01	2.64	0.63	4.12	0.87	0.17	0.26
			Kelley	6.61	0.96	5.25	1.59	0.25	0.60	6.32	0.51	5.56	1.83	0.36	1.05	3.14	0.61	3.92	0.95	0.21	0.22

increased from the all-NO_3^- level to a maximum concentration at the $\frac{2}{3}$-NO_3^- level, then decreased markedly with increments of NH_4^+ in the substrate. Also, at high NO_3^- supply, the accumulation of potassium was appreciably greater in the bottom leaves than in the top leaves; but, at high NH_4^+ supply, the potassium content of both top and bottom leaves was approximately equal. Both varieties responded similarly.

From Figure 5, it is evident that variations in the relative proportions of the ionic forms of nitrogen in the substrate had a very pronounced

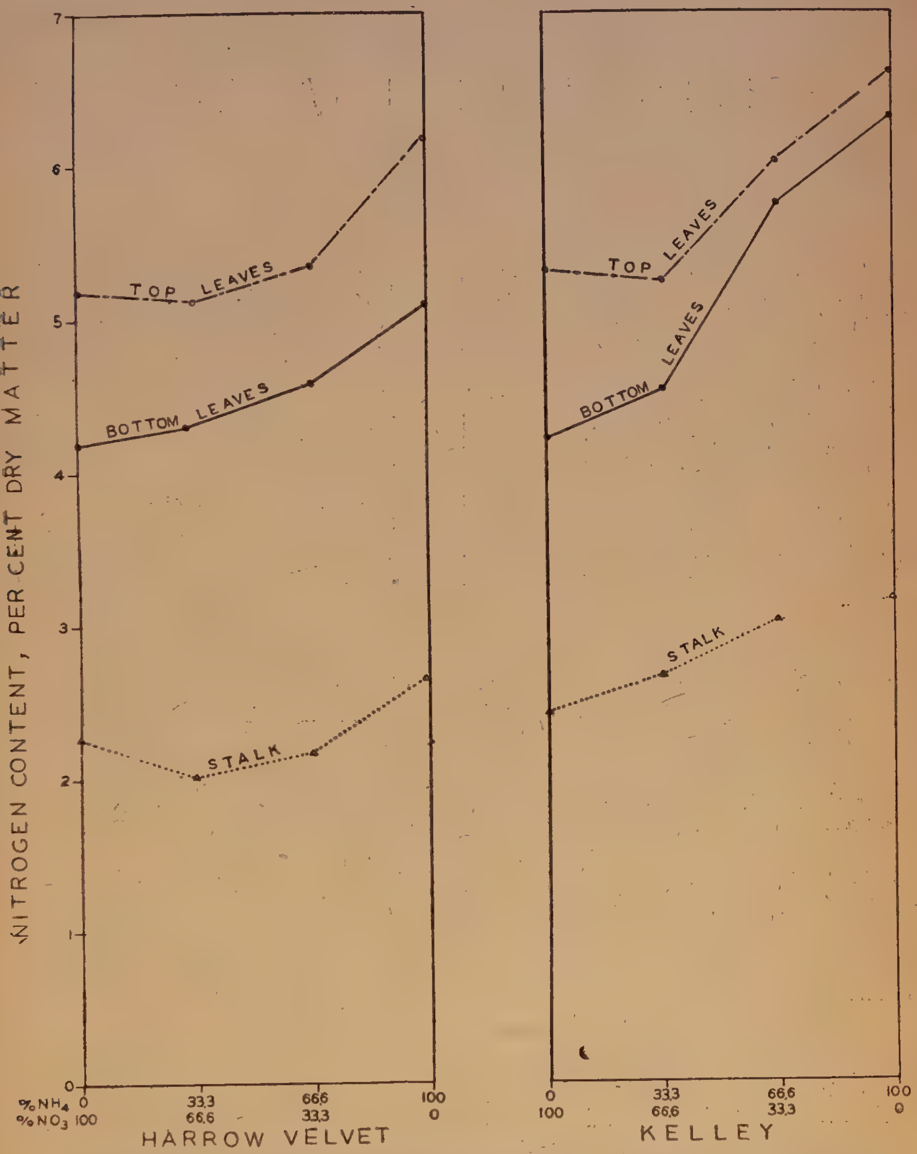

FIGURE 2. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of nitrogen in tobacco tissue.

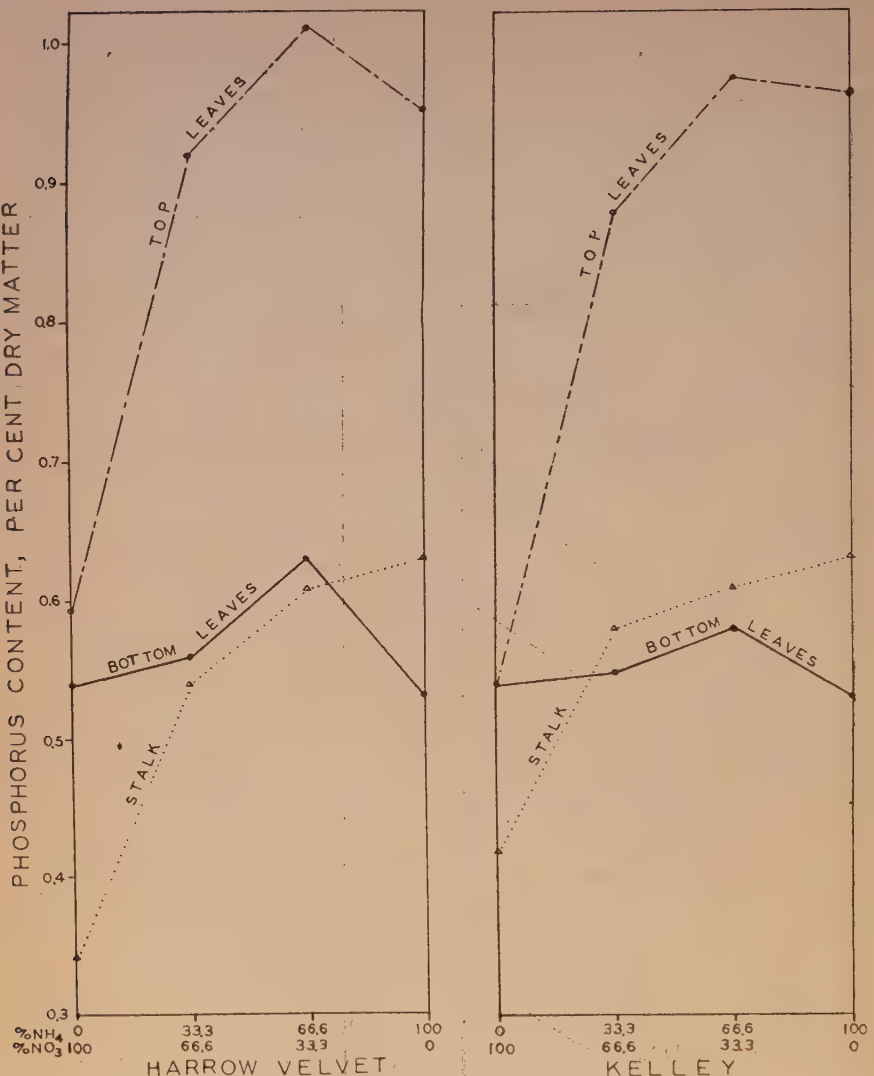

FIGURE 3. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of phosphorus in tobacco tissue.

influence on the accumulation of calcium in the tissues. Each successive edcrease in NO_3^- and increase in NH_4^+ in the nutrient supply had a depressing effect on the accumulation of calcium in all 3 fractions of the tissue. The difference between the 2 varieties in this regard was insignificant.

Figure 6 shows a highly depressing effect of the NH_4^- ion on the accumulation of magnesium in the leaf tissue. The magnesium content of both top leaves and bottom leaves decreased markedly with decreasing NO_3^- and increasing NH_4^+ in the substrate over the range 0 to $\frac{2}{3}$ NH_4^+, then increased slightly at the all-NH_4^+ treatment, except in the bottom leaves of Harrow Velvet. In both varieties, the magnesium content was

highest in the bottom leaves, next highest in the top leaves, and lowest in the stalk. The content of magnesium in the stalk was very constant in treatments 1, 2, and 3, but rose appreciably in the all-NH_4^+ treatment. The varietal difference with regard to magnesium accumulation in the tissues was not significant.

A low content of sulphur (Figure 7) in the top leaves was associated both with all-NO_3^- nitrogen and also with all-NH_4^+ nitrogen in the substrate, but the accumulation of sulphur increased markedly in treatments 2 and 3. In the bottom leaves, the accumulation of sulphur was depressed greatly at 100% NO_3^- and reached a maximum concentration at the $\frac{2}{3}$-NH_4^+ nitrogen level. In the stalk tissue, the influence of the ionic forms of nitrogen on

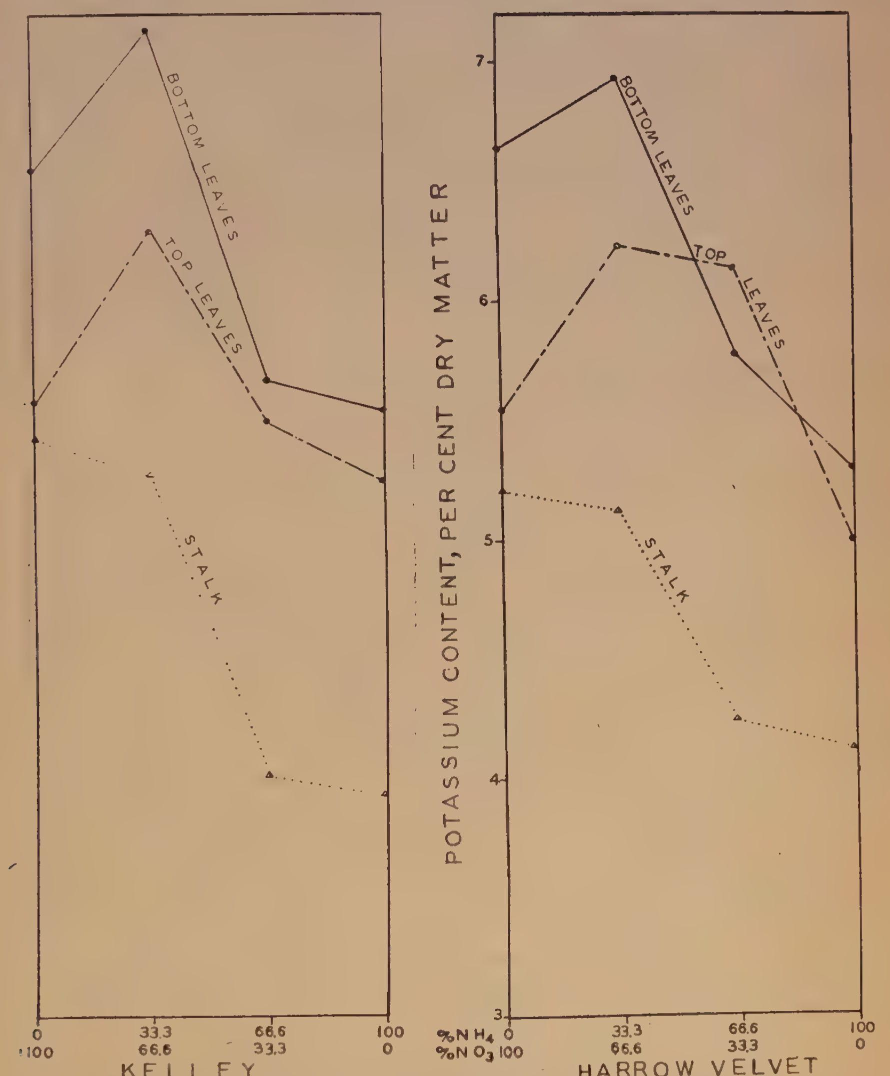

FIGURE 4. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of potassium in tobacco tissue.

the content of sulphur was not pronounced; however, the amount of this element was apparently depressed at both high NO_3^- and high NH_4^+. The 2 varieties did not differ significantly with regard to sulphur accumulation.

DISCUSSION

Inherent physiological differences between plant species are a matter of common knowledge, and such differences have been recognized within a limited number of species. However, no report of physiological studies of varietal differences in tobacco has even come to the attention of the writer.

In the present study in which the fresh weight yield has been the criterion of growth, the differential varietal response of burley tobacco to ionic forms of nitrogen was not statistically significant. That is, the

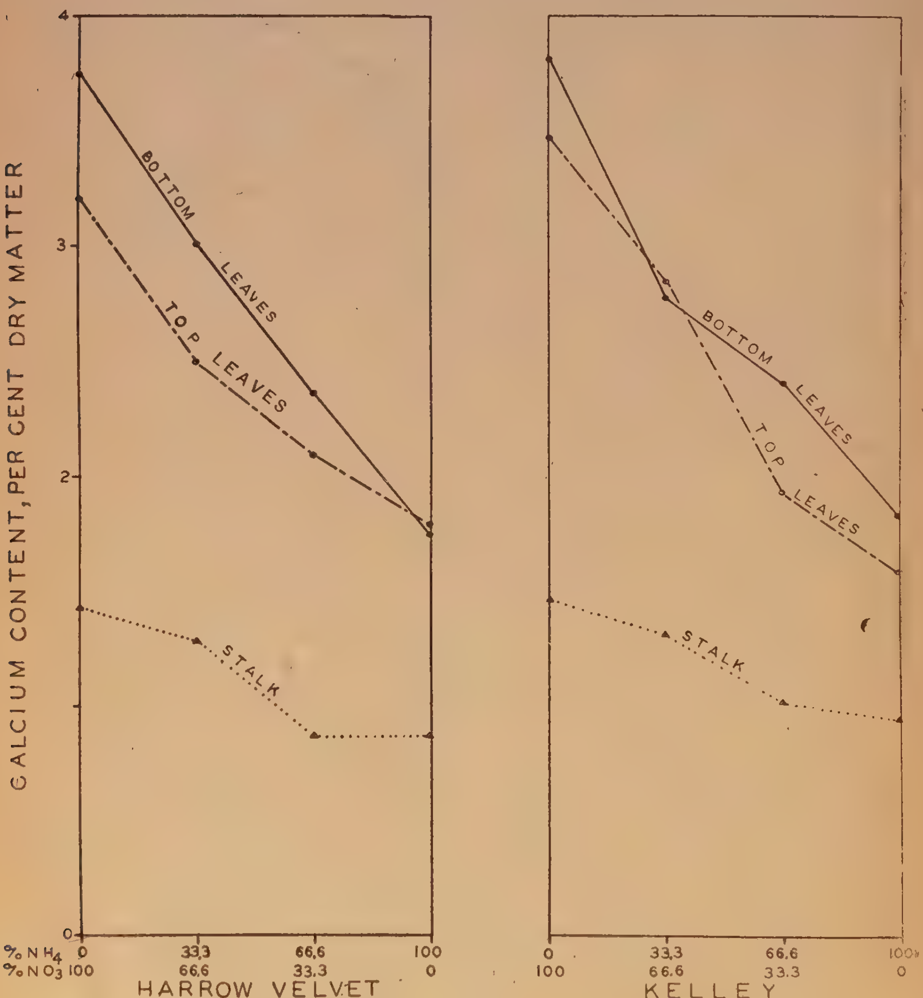

FIGURE 5. Effect of concentration of ionic forms of nitrogen in the substrate on aucumulation of calcium in tobacco tissue.

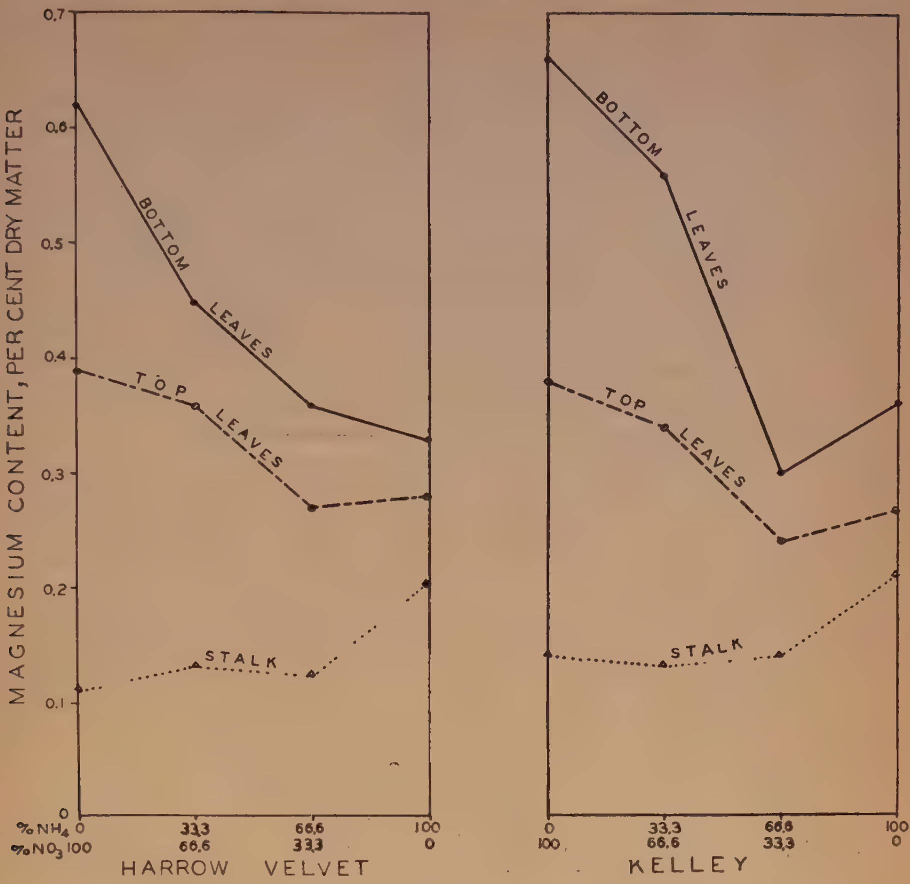

FIGURE 6. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of magnesium in tobacco tissue.

growth of one variety on nitrate nitrogen relative to its growth on ammonium nitrogen did not differ significantly from that of the other variety. However, both varieties made significantly better growth when all, or $\frac{2}{3}$, of the nitrogen supply was in the nitrate form, the yield decreasing with increments of ammonium nitrogen. Thus, it is indicated that both varieties are characterized by the ability to utilize nitrate nitrogen more efficiently than ammonium nitrogen as they were supplied in this test. Also, the yield of Harrow Velvet was significantly higher than that of Kelley over the entire range of nutrient solutions.

The chemical analytical data, giving the content of the nutrient elements in the plant material at harvesting time, show a pronounced influence of the concentration of ionic forms of nitrogen, in the nutrient solution, on the accumulation of the nutrient elements in the plant, and an explanation of this influence is sought.

It is generally acknowledged that the rate of absorption of nutrient ions by the roots is a function of the concentration of the ions in the nutrient medium, however, other factors are involved. Ions differ widely in the

rapidity with which they are absorbed and the rate of absorption is related to their mobility. There is evidence that K^+ is absorbed more rapidly than Mg^{++}, and the latter more rapidly than Ca^{++} (13) (3). The anions dealt with in the present study may be arranged in order of decreasing rate of penetration as follows $NO_3^- > H_2PO_4^- > SO_4^=$ (13).

That one ion may affect the absorption of another is well known and Hoagland *et al.* (5) have postulated a competitive effect in ionic penetration. They suggest that, through competitive action of ions of similar charge, one cation may depress the absorption of another, while an active anion may retard the absorption of the less active. Furthermore, the rate of absorption and accumulation of a cation is increased by a rapidly absorbed anion.

The marked decrease in the accumulation of potassium in the tissue when nitrogen was supplied as NH_4^+ as compared to that when nitrogen

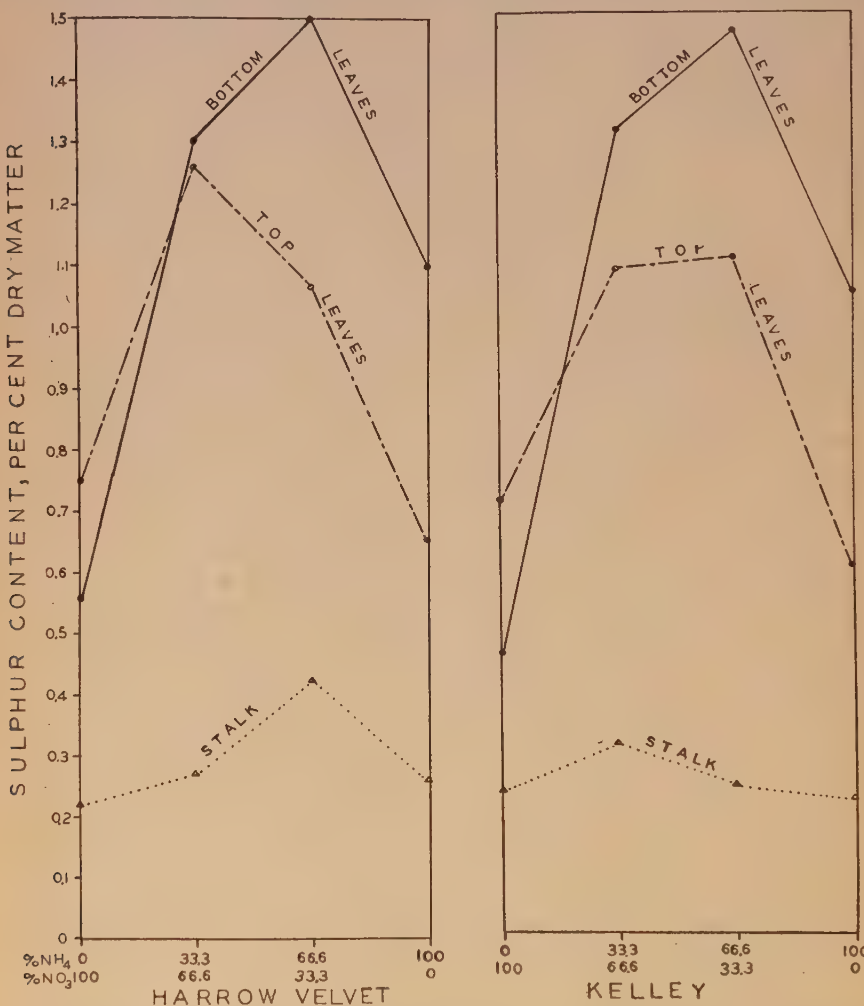

FIGURE 7. Effect of concentration of ionic forms of nitrogen in the substrate on accumulation of sulphur in tobacco tissue.

was supplied as NO_3^-, may be explained on a basis of Hoagland's hypothesis of ionic penetration. The presence of cation nitrogen (NH_4^+) in the nutrient solution seemed to decrease the rate of absorption of the K^+ ions of similar charge by interionic competition. Furthermore, the concentration of NO_3^- in the nutrient solution is a factor to be considered since the rate of absorption of potassium, a cation, may be accelerated by the absorption of the mobile anion, NO_3^-.

Figure 5 shows that, in all 3 fractions of the tissue, increasing content of calcium, a slowly-absorbed cation, was directly related to increasing NO_3^- concentration in the nutrient solution, and inversely related to increasing concentrations of the cation, NH_4^+, in the solution. Both relations are in harmony with the hypothesis of ionic penetration. These results are in close agreement with those of Jacobson and Swanback (7) who report that an increased proportion of nitrate nitrogen over ammonical nitrogen in the nutrient supply was associated with high calcium in the plant material of tobacco.

The analytical data, showing that the concentration of magnesium in the leaf tissue was low when nitrogen was supplied as NH_4^+, as compared to that when nitrogen was supplied as NO_3^-, present confirmatory evidence that the chlorotic condition of the plants grown on high NH_4^+ supply was correctly diagnosed as magnesium deficiency. These results throw further light on the magnesium hunger, or "sand drown," picture under certain field conditions. It was reported by Anderson *et al.* (1) that magnesium hunger was very severe on tobacco plants grown on plots to which nitrogen was applied as sulphate of ammonia. In explanation, these workers suggested the possibility of the magnesium combining with the sulphate radical, forming magnesium sulphate, a highly soluble salt, which later was leached from the surface soil by the heavy rain. In this regard, it seems highly significant that, in the present sand-culture experiment, magnesium hunger was associated with high ammonium nitrogen in the substrate under conditions which precluded the possibility of a deficiency of magnesium being created by leaching. Here, magnesium, as well as the other nutrient elements, was supplied continuously by the constant flow method.

The influence of ionic forms of nitrogen on the accumulation of magnesium in the plant is explainable according to Hoagland's hypothesis of ionic penetration. Figure 6 shows that the accumulation of magnesium in both top leaves and bottom leaves was accelerated by increase in the concentration of the mobile anion, NO_3^-, in the nutrient medium, but was retarded by increase in the concentration of the NH_4^+ ion because of interionic competition. That is, the rate of absorption of magnesium, a slowly-moving anion, was increased by the presence of nitrate, a rapidly-moving anion. Conversely, the rate of absorption of magnesium was retarded by the competitive ionic penetration of the other cation, NH_4^+. Both relations conform to Hoagland's hypothesis.

Phosphorus was a variable factor in the nutrient supply. In the stalk and top leaves, which include the regions of most rapid growth, the content of phosphorus was directly related to the concentration of this element in the nutrient medium. Also, in these fractions, the content of phosphorus which is absorbed as an anion was directly related to the concentration of

cation nitrogen and inversely related to the concentration of anion nitrogen in the substrate, in accordance with the hypothesis of ionic penetration. However, no definite relationship was manifested between the content of phosphorus in the bottom leaves and either the ionic forms of nitrogen in the nutrient medium, or the concentration of phosphorus in the nutrient medium.

Sulphur, also, was a variable factor in the nutrient supply; however, the content of this element in the tissue did not vary in proportion to its concentration in the nutrient supply. Also, the relationships between the ionic forms of nitrogen, and the accumulation of sulphur in the plant, are not in full agreement with the general hypothesis of interionic relations.

The results of the chemical analyses show a difference between the metabolism of nitrate nitrogen and ammonium nitrogen in both varieties. When nitrogen was supplied as NH_4^+, there was an increase in the accumulation of total nitrogen in all 3 fractions of the tissue over that when nitrogen was supplied as NO_3^-. This result, coupled with the relatively poor growth made on ammonium nitrogen, is indicative of inefficient ammonium-nitrogen utilization by the burley tobacco varieties tested.

It is evident that the concentration of ionic forms of nitrogen in the nutrient medium had a significant influence on the content of the major nutrient elements in the tissue of burley tobacco at harvest; however, the varietal differences in this regard were insignificant. Moreover, the interionic relations herein shown to exist have been demonstrated for only the 2 tobacco varieties tested, and only under the conditions of this experiment. The responses of other varieties to the same treatments, and the responses of the same varieties under different conditions, could be determined only by further study.

SUMMARY

Two varieties of burley tobacco, namely, Harrow Velvet and Kelley, were grown in sand culture on a range of nutrient solutions made up of varying proportions of nitrate and ammonium nitrogen. The differential response by varieties to the 2 ionic forms of nitrogen was not statistically significant. One variety did not make relatively more growth on nitrate nitrogen, compared to its growth on ammonium nitrogen, than did the other variety.

The varieties and treatments were both sources of significant variation; Harrow Velvet yielded higher than Kelley, and both varieties yielded lower at the ammonium end of the solutions.

Top leaves, bottom leaves, and stalk tissues of each variety from each treatment were analysed for total N, P, K, Ca, Mg and S. While the content of these elements in the plant material was greatly affected by the relative proportions of the ammonium and nitrate ions in the nutrient medium, the varietal differences in this regard were insignificant.

It was determined that the ionic forms of nitrogen in the nutrient medium had either a positive or negative effect on the content of the elements in the tissues, in agreement with the hypothesis of interionic relations advanced by Hoagland *et al.* An increased proportion of nitrate nitrogen and a decreased proportion of ammonium nitrogen in the nutrient solution, resulted in an increase in the content of K, Mg, and Ca and a decrease in the content of N and P in the plant material.

REFERENCES

1. ANDERSON, P. J., N. T. NELSON, and T. R. SWANBACK. Conn. Agr. Exp. Sta. Bull. 10, p. 61T. 1928.
2. GREGORY, F., and F. CROWTHER. A physiological study of varietal differences in plants. Part 1. A study of the comparative yields of barley varieties and different manuring. Ann. Bot. Lond. 42 : 757-770. 1928.
3. HAAS, A. R. C., and H. S. REED. The absorption of ions by citrus and walnut seedlings. Hilgardia 2 : 67-106. 1926.
4. HARVEY, P. H. Hereditary variation in plant nutrition. Genetics 24 : 437-461. 1939.
5. HOAGLAND, D. R., A. R. DAVIS, and P. L. HIBBARD. The influence of one ion on the accumulation of another by plant cells with special reference to experiments with *Nitella*. Plant Physiol. 3 : 473-486. 1928.
6. HOFFER, G. N. Some influences in the functioning of selfed lines of corn under varying nutritional conditions. Jour. Amer. Soc. Agron. 18 : 324-334. 1926.
7. JACOBSON, H. G. M., and T. R. SWANBACK. Relative influence of nitrate and ammonical nitrogen upon the intake of calcium by tobacco plant. Plant Physiol. 8 : 340-342. 1933.
8. LAMB, C. A., and R. M. SALTER. Response of wheat varieties to different fertility levels. Jour. Agr. Res. 53 : 129-143. 1936.
9. LAMB, C. A., and R. M. SALTER. Response of oat varieties to different fertility levels. Jour. Agr. Res. 55 : 785-793. 1937.
10. LYNESS, A. S. Varietal differences in the phosphorus feeding capacity of plants. Plant Physiol. 11 : 665-688. 1936.
11. OFFICIAL AND TENTATIVE METHODS OF ANALYSIS OF THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. 1930.
12. PUCHER, G. W., C. S. LEAVENWORTH, and H. B. VICKERY. Determination of total nitrogen of plant extracts in the presence of nitrates. Jour. Ind. and Eng. Chem. Anal. Ed. 2 : 191. 1930.
13. SEIFRIZ, W. Protoplasm. McGraw-Hill Book Co., New York. 1936.
14. SMITH, S. N. Response of inbred lines and crosses in maize to variations of nitrogen and phosphorus supplied as nutrients. Jour. Amer. Soc. Agron. 26 : 785-804. 1934.
15. SPRINGFIELD, G. H., and R. M. SALTER. Differential response of corn varieties to fertility levels and to seasons. Jour. Agr. Res. 49 : 991-1000. 1934.

SEED POTATO DISTRICTS AND VIRUS DISEASES IN QUEBEC[1]

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In 1928, trials were undertaken to determine: the districts most suitable for the growing of certified seed potatoes; the possibilities of maintaining in a district certified seed commercially-free from virus diseases; if certified seed grown in one district could be grown advantageously in another district; to what extent virus diseases had either spread or decreased in the tuber unit seed plots in each district; and the reasons why the truck crop and potato growers in the vicinity of Montreal preferred changing their seed each year.

In 1932, these trials were discontinued on account of the impossibility of visiting the same regularly and at the proper time for the examination of virus diseases. Field inspection of these plots could be made but twice during the growing season and then often under unfavourable conditions brought about by the damage to the foliage caused by insects, fungous diseases and the effects of late planting. These difficulties sometimes rendered it impossible to determine accurately the exact percentage of virus diseases in the plants.

At the suggestion of Mr. John Tucker, formerly Seed Potato Specialist for the Dominion Department of Agriculture, the author decided during the winter of 1938–39 to index potatoes from these plots in order to determine, as accurately as possible the percentage of transmission of virus diseases by sucking insects during the previous growing season. The tuber index method was chosen because other methods of detecting virus diseases were found quite unsatisfactory for this kind of work.—In 1938, very few tubers from these plots were indexed due to lack of space in the greenhouse at the local plant pathological laboratory.—In 1939, the Potato Section of the Horticulture Service of the Quebec Department of Agriculture erected at Ste. Anne de la Pocatiere, at the Agricultural School, two greenhouses 66′×25′. In these greenhouses the tuber indexing work (2) was carried out in co-operation with the provincial officials.

GEOGRAPHICAL DISTRIBUTION OF SEED POTATO DISTRICTS

In 1928, when this work was first undertaken, the Province of Quebec was divided into 5 districts. District Number 1, comprised seed potato centres located in the southern and the south-western parts of the province, that is to say, those areas between the 45° and 46° N. District Number 2, included the seed potato sections in the eastern, central and western parts of the province located between 46° and 47° N. District Number 3, comprised the parishes located in the eastern and central parts of the province situated between 47° and 48° N. District Number 4, included all the parishes growing potatoes located in the northern, north-eastern and north-western parts of the province including the areas located between 48° and 49° N. District Number 5, grouped all seed potato growing sections located above 49° N.

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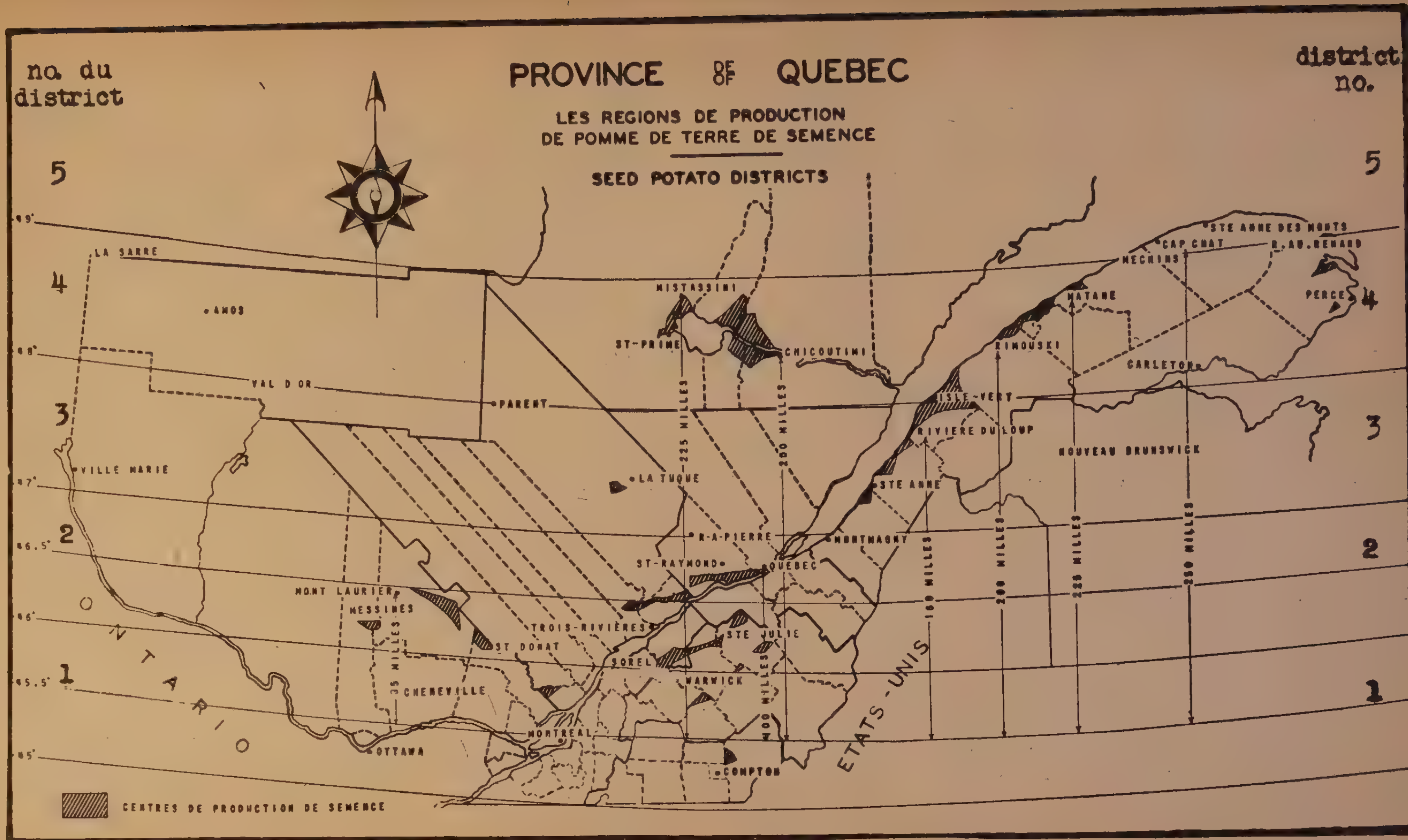

FIG. 1. On this map the striped diagrams indicate in each district where the trials were conducted. It is pointed out that some seed potato centres such as Mistassini, Chicoutimi, Rimouski and Matane are located over 200 miles north of Montreal which is on the 45.5° N.

There were a certain number of seed potato growing centres in each district and trials were conducted in each centre. Locations of these seed potato centres may be seen on the map which follows.

When this work was first undertaken, a survey was conducted in each district, to obtain information on the acreage planted with certified seed and inspected with the view to certification. The total acreage inspected in the Province of Quebec is 2,200 acres. Table 1 shows the percentage of acreage of certified seed inspected in each district during the years 1929 to 1932 compared with the period 1942 to 1945.

Table 1—Average % Acreage of Crops inspected and certified in each district

District No.	Average % acreage inspected during the years		Average % acreage certified from 1942 to 1945 in the grades (1)		
	1929 to 1932	1942 to 1945	F	F–A	C
1	17.5	8.0	1.9	3.40	8.1
2	35.0	25.5	42.6	16.15	54.8
3	5.0	12.0	9.9	16.50	9.8
4	41.0	54.0	45.6	63.70	27.3
5	1.5	0.5	—	0.25	—

(1) "F"—Foundation. "F-A"—Foundation-A. "C"—Certified.

The Foundation and Foundation-A grades of certified seed potatoes were not established until 1942. Only one grade "Certified Seed" was known previous to 1942.

Table 1 shows that from 1929 to 1932 inclusively, 47.5% of the total production of certified seed potatoes was grown in districts 3, 4 and 5. The figures for the years 1942 to 1945 inclusively show that 66.5% of the acreage was grown in the same districts indicating an increase of 19% in the production of certified seed potatoes in the districts located above 47° N. Certified seed production in District Number 5 decreased 1% during the period 1942 to 1945. This was due largely to the occurrence of the scab disease which rendered the potatoes unsuitable for seed purposes. The data in Table 1 also show that 45.6% of the Foundation, 63.9% of the Foundation-A and 27.3% of the certified grade seed potatoes was grown in Districts 4 and 5. It is also significant that 62.9% of the Certified grade was grown in Districts 1 and 2 located in the southern, south-eastern and the south-western parts of the province between 45° and 46° N.

In the districts where these trials were carried out, the plots were planted exclusively with tuber-indexed seed of the Green Mountain variety. The only exception was in District Number 2 where about 50% was of the Irish Cobbler variety. On the farms where these trials were conducted only Foundation, Foundation-A and Certified seed potatoes were planted and inspected with the view to certification. These plots were planted at distances varying from 200 to 1000 feet from table stock potato fields. Only one plot was planted on each farm and in the same district plots were often located a few miles from each other. The plots were planted by the tuber unit method and the size varied from ¼ to 1 acre. The first roguing of these tuber unit plots for removal and destruction of diseased units was

made at the beginning of July before sucking insects (aphides) appeared. In these trials, no insecticides were used to control aphides nor herbicides to destroy potato tops before complete maturity. On the majority of farms Bordeaux mixture was used for the control of late blight. The plots were usually harvested 10 to 15 days after the tops matured about the end of September or middle of October. The tubers from these plots were stored separately from other stocks. The grower in each case chose (according to the size of his plot) from 400 to 1200 tubers weighing from 6 to 10 oz. each. These tubers were sent in December to the Ste. Anne de la Pocatiere greenhouses for indexing in order to determine the amount of infection with virus diseases.

The tuber-indexing began early in January of each year. Each lot indexed comprised tubers from the plots in each district. The final readings on plants in each lot were made in February, March and April. The mother tubers (whose eyes had shown no disease in the greenhouse) were returned to the grower for the planting of his tuber unit plot the following season.

RESULTS OF THE TRIALS

Table 2 shows the invasion of tuber indexed seed with mosaic and leaf-roll in each district during the period 1942 to 1946. The results of the trials conducted from 1939 to 1941 are not included in this table because it was not possible to determine accurately from the small number and restricted size ($\frac{1}{10}$ acre) of the plots used, the amount of virus disease in each case. No trials were made in District Number 5 but there were a few plots located in District Number 4 a few miles from the border of District Number 5 (Fig. 1).

DISCUSSION

The data obtained from these trials give at least a partial answer to the question of the most suitable certified seed potato districts. There is considerable evidence to show that in Quebec Province the prevalence of virus diseases (more especially leaf-roll) varies considerably from season to season, from district to district, and even from locality to locality. Local variation in the incidence of the leaf-roll disease suggests the necessity of determining and limiting, especially the areas used for the production of Foundation seed. Leaf-roll is undoubtedly a very important limiting factor in the production of seed potatoes. The rapid spread of this disease in some districts is believed to be due to an increase in the number of aphides late in the growing season. The figures in Table 2 indicate that the seasonal incidence of leaf-roll in the seed plots is greater in Districts 1, 2 and 3, than in District Number 4. The results of these trials during the years 1942 to 1946 show that in District Number 4 the average percentage of leaf-roll infection was 2.4 compared with 12.5 for District Number 1. These results also clearly indicate that there was less leaf-roll transmission in the seed plots grown closer to the north and north-eastern parts of the province. The above results confirm the findings of other workers, especially those of Folsom (3) of the United States.

Table 2 also shows that the mosaic disease varies from year to year and in a season from district to district and even from locality to locality. In general the percentage of mosaic was less than that of leaf-roll, except

TABLE 2.—SUMMARY OF RESULTS WITH TUBER-INDEXED SEED PLANTED BY THE TUBER UNIT METHOD IN DIFFERENT SEED POTATO DISTRICTS

Year	No. of district	No. of farms	No. of bags (75 lb.) indexed seed planted	No. of tubers removed and indexed	Virus diseases found according to tuber-index test	
					Mosaic	Leaf-roll
					%	%
1942–43		1	2	340 (1)	1.47	2.15
1943–44	1	2	3	710 (1)	4.65	7.61
1944–45		3	5	2,109	3.13	5.12
1945–46		4	14	3,887	8.90	18.36
	Four-year average				6.40	12.50
1942–43		4	6	1,185 (1)	3.88	12.69
1943–44	2	2	8	473 (1)	2.98	2.96
1944–45		8	4	5,440	3.87	3.11
1945–46		9	34	4,462	2.89	6.47
	Four-year average				3.40	5.30
1942–43		9	39	5,825	4.33	8.03
1943–44	3	10	36	10,083	4.27	5.12
1944–45		7	63	6,115	3.24	3.99
1945–46		9	45	10,908	3.36	4.48
	Four-year average				3.80	5.20
1942–43		11	31	8,245	4.23	3.31
1943–44	4	14	52	6,464	2.40	2.72
1944–45		24	40	13,364	3.31	1.53
1945–46		35	84	20,327	3.58	2.56
	Four-year average				3.40	2.40

(1) An accurate determination of the amount of virus disease could not be made because less than 400 tubers from each seed plot were indexed in each case.

in District Number 1 where seasonal variations were more pronounced. The average percentage of mosaic infection in the seed plots was 6.4, 3.4, 3.8 and 3.4 in Districts 1, 2, 3, and 4, respectively. These figures indicate that there was very little variation in the percentage of mosaic infection in Districts 2, 3 and 4 but the transmission of the disease in these areas was much lower than in District Number 1.

According to the date shown in Table 2, the location of a district or a centre, even a farm, may have an influence on the quality of the seed (1). It is apparent that seed grown in District Number 1 degenerates rapidly due to invasion by virus diseases, while that in District Number 4 shows very little evidence of these destructive diseases. These diseases even tend to eliminate themselves in some sections of this District. Our trials, observations and field inspections also demonstrate that it is undesirable to plant and multiply certified seed potatoes grown in Districts 1 and 2 in Districts 4 and 5 because such seed rarely qualifies for certification in the latter areas. This confirms the finding of other workers, especially Macoun (4), that northern-grown seed potatoes are preferable for seed purposes.

Table 3 includes figures taken from the annual tuber indexing reports (5) showing the average percentage of infection of mild and severe mosaic as well as severe and mild leaf-roll for each district.

TABLE 3.—AVERAGE % OF MILD AND SEVERE MOSAIC AND LEAF-ROLL IN EACH DISTRICT

District No.	Average % of virus diseases according to tuber indexing test(¹)			
	Mild mosaic	Severe mosaic	Severe leaf-roll	Mild leaf-roll
1	4.2	2.2	1.80	10.7
2	2.9	0.5	0.60	4.7
3	3.1	0.6	0.10	5.0
4	3.0	0.4	0.02	2.3

(¹) Four-year average.

The results of the trials summarized in Table 3 reveal that the average percentage of infection of mild and severe mosaic varied from district to district. In District Number 1, the incidence of severe mosaic was nearly 6 times greater than that in District Number 4 and about 4 times higher than that in District Number 2. This indicates that mosaic increased as the seed plots were located towards south and south-western parts of the province.

The data in Table 3 also shows that the average percentage of severe leaf-roll infection in District Number 4 is only 0.02 compared with 1.8 in District Number 1. There is an even greater difference in the incidence of mild leaf-roll in these districts being 2.3% in District Number 4 and 10.7% in District Number 1. These results revealed that the leaf-roll disease increased as the seed plots were located in the southern section of the province. Therefore, the localities most suitable for seed selection and multiplication of potato strains would be those located above the 48° N.

A study of the tuber indexing reports on stocks from different localities in each District also shows that the total percentage of virus disease varies from one locality to another and often differs in a season from one farm to another. It was found that in some localities in the same district the amount of leaf-roll infection was negligible and even tended to disappear. It was also discovered that the mosaic disease varied in the same locality which seems to prove that there are sections in the same districts, more especially in District Number 4, where ideal conditions exist for the multiplication of Foundation seed stocks. These favourable centres are often well isolated and restricted in size.

On the basis of these findings it would be advisable to choose from these preferred centres the areas most suitably adapted to the growing of Foundation seed stocks. Owing to the fact that certain fruit trees, shrubs and weeds serve as overwintering hosts for the aphides which transmit leaf-roll and mosaic, these hosts should be located and destroyed in the areas chosen for the Foundation seed production.

SUMMARY AND CONCLUSION

Certified seed production in the Province of Quebec is centered in 5 main districts. Trials were conducted on 40 farms in 25 localities in these districts to determine the areas most suitably adapted to the growing of Certified seed potatoes, especially the Foundation and Foundation-A grades.

The results of these trials showed that the production of seed potatoes is gradually shifting in a north and north-easterly direction in the Province. Fifty-four percent of the certified grades of potatoes are now grown above 48° N.

The methods employed in connection with these tests were essentially the same each year. The seed potatoes used for these trials were all tuber-indexed in the greenhouse the preceding winter and only disease-free tubers of the Green Mountain and Irish Cobbler varieties were chosen. All the plots were planted according to the tuber unit method. The total number of tubers removed in the fall from each seed plot and indexed ranged from 400 to 1200 according to the size of the plots. The plots varied in size from $\frac{1}{4}$ to 1 acre. The percentage of virus infection in each generation was determined during the winter months in the greenhouse by the tuber-index method. From 16,000 to 39,000 tubers were tested annually which represents that each year from 125 to 300 bushels of seed potatoes from 25 parishes of this province were subjected to the tuber-index test.

The results of these trials including those from the field and tuber-index tests showed that the incidence of such disease as leaf-roll and mosaic varied according to the season, district, locality and isolation conditions. It was apparent that the leaf-roll disease increased as the test plots were grown closer to the south and south-western parts of the province. The fact that conditions in this section of the province enhanced the occurrence of the leaf-roll disease, explains in part at least, why growers in the Montreal district found it necessary to change their seed potato stocks every year to ensure a supply of seed free from this important virus disease. The transmission of severe mosaic disease decreased as the plots were located towards the north and north east. Noteworthy, is the fact that leaf roll tends to eliminate itself in certain districts.

In these trials we have noted that, in general, in cool regions which are hilly, and have a high elevation, if potato fields are far apart better seed is produced than in warmer sections which are level, lower and in which fields are close together.

The results of the several trials definitely indicated that it is in the north and northeastern districts as well as those which are in proximity to the sea that the growing of certified seed potatoes, especially the Foundation grades, should be intensified. In the less favourable districts, especially in the south and south-western parts of the province, certified seed growing should be discontinued and the production of table stock potatoes encouraged.

Worthy of mention in connection with these trials is the fact that Bacterial Ring Rot was never found in the tuber unit seed plots or in the greenhouses during the course of these trials. This seems to indicate that the combination of tuber-indexing and tuber unit planting may be a practical means of controlling this important disease.

It is hoped that the information accumulated in connection with these trials will serve as a useful guide to the establishment of centres most suitably adapted for the growing of certified seed potatoes, especially the Foundation grades.

REFERENCES

1. Baribeau, B.—Où produire des semences de pommes de terre sélectionnées. Bulletin des Agriculteurs, Montreal. Vol. 23. No. 13. pp. 44–45. 1938.

2. Baribeau, B., et Roger Gagnon.—L'indexage des pommes de terre de semence. Agriculture. Vol. III. No. 2. pp. 123-135. 1946.

3. Folsom, Donald,—Green Mountain tuber line seed plots. Progress Report. Bull. 405, p. 503. 1941.

4. Macoun, W. T.—The potato and its culture. Central Experimental Farm, Ottawa. Bull. 90, pp. 17–27. 1919.

5. Plant Protection Division.—Reports on tuber indexing and field inspection work. Dept. Agr. Sci. Service, Ottawa. 1940-1945.

ERADICATION OF POISON IVY (*RHUS RADICANS* L.)

II. PRELIMINARY RESULTS WITH 2,4-DICHLOROPHENOXYACETIC ACID[1]

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[Received for publication November 6, 1946]

Recent interest in the herbicidal activity of phenoxyacetic acids has resulted in considerable experimental work to evaluate their weed killing properties. In 1945, at Ottawa, 2,4-dichlorophenoxyacetic acid was included among the herbicides being tested for the eradication of poison ivy. The results obtained from the 1945 trials are of sufficient interest to be placed on record. Further experiments are underway and will be reported when complete results are obtained.

All applications were made as an aqueous spray to the poison ivy foliage by means of a knapsack sprayer of 3-gal. capacity. The experimental plots were 100 sq. ft. in area and were situated at Wrightville, Quebec, on very shallow soil over limestone bedrock. They were on a railroad right-of-way, and the edge of some of the plots included the slight shoulder of fill by the tracks. The aqueous spray solutions were prepared by dissolving the required amount of 2,4-dichlorophenoxyacetic acid in melted carbowax 1500, then adding this solution with stirring to the gallon of water. The carbowax was used in amounts sufficient to give a 0.5% solution regardless of the concentration of 2,4-dichlorophenoxyacetic acid. The gallon of solution was sufficient to cover each plot twice.

Estimates of poison ivy cover were made visually and represent the percentage of the area of the plot covered with poison ivy foliage.

The results obtained are given in Table 1.

From the estimates of poison ivy cover made in July of the summer following the application of 2,4-dichlorophenoxyacetic acid, it is apparent that best results were obtained when the acid was applied to young plants in June and in concentrations of 1000 p.p.m. or greater.

TABLE 1.—THE EFFECTIVENESS OF 2,4-DICHLOROPHENOXYACETIC ACID AS A HERBICIDE WHEN APPLIED AS A SPRAY TO POISON IVY PLOTS OF 100 SQ. FT. IN AREA

Exp. No.	Plot No.	Date of application	Amount of herbicide applied		Poison ivy cover (%)	
					Before treatment	In July of first year after application
		1945	gal.	p.p.m.		
21	9	June 26	1	250	80	35
	10	June 26	1	500	85	30
	11	June 26	1	1000	85	5
	12	June 26	1	2000*	90	5
22	2	June 25	1	1000	85	10
	4	July 18	1	1000	95	75
	6	Aug. 9	1	1000	90	80
	8	Sept. 12	1	1000	85	80

* A precipitate occurred when carbowax containing this amount of 2,4-dichlorophenoxyacetic acid was dissolved in water. Herbicidal strength, therefore, would be less than 2000 p.p.m.

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BOOK REVIEW

THE NEW GENETICS IN THE U.S.S.R.—P. S. Hudson and R. H. Richens, Imp. Bureau of P.B. and Genetics, Cambridge, 1946, pp. 88.

During the past ten years or so there has been much confusion in the minds of people on this continent and elsewhere regarding a school of thought which has been developing in the field of genetics in the U.S.S.R. This school, led and vigorously defended by Lysenko and Prezent, differs profoundly from that recognized by the majority of modern biologists. It is based on a philosophy—in this case the philosophy of dialectical materialism—rather than on conceptions commonly held by scientists outside of Russia. It is definitely opposed to the Mendelian theory, partly because this theory lends support to the opponents of those who are trying to defend the theory of social equality. The points of view held by the two schools, therefore, have led to controversies which have been extended far beyond the borders of pure science. Prezent himself says that "anyone who does not understand the enormous social-class significance of our controversy will fail to understand the essence of our controversy."

The Imperial Bureau of Plant Genetics has followed closely the developments which have been taking place and has published abstracts from time to time of the leading works published in Russia. The present bulletin, however, is the first real attempt to present a complete and impartial story and to submit the claims made to a careful scientific analysis. The authors have rendered a distinct service to a wide range of readers by clarifying the Russian points of view and in examining their validity.

Those interested in this question should read the bulletin carefully. They will find it extremely well written and most thought-provoking. An excellent and much more complete review of this bulletin by Prof. Eric Ashby appears elsewhere so no extended comments need be made here.*

Prof. Ashby not only discusses the salient points raised by the authors but supplements these from his own personal observations. Thus he is able to furnish first-hand information as to the experimental technique employed by Lysenko and his followers. This by all modern standards recognized outside the U.S.S.R. must be regarded with suspicion. He expresses the opinion that the Lysenko school is on the wane and that most biologists in the U.S.S.R. have actually been embarrassed by the claims made therefor.

L. H. NEWMAN

ERRATA

In the September issue of Scientific Agriculture (Vol. 26, No. 9, 1946) amend the second paragraph on page 424 to read as follows:

The equipment described has been used for colour photography, and some examples have been published elsewhere (4). Kodachrome professional type B film, having a colour temperature rating of 3200° K. (1, 5) and a film speed of 6 Weston units, was used.

In the same issue, amend the last sentence on page 445 to read as follows: If a dryer is not available, Tests 8, 9, and 10 are suitable, although the drying time of the samples will range from 12 to 20 hours respectively, for each test.

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*Ashby, Eric, Prof. Genetics in the U.S.S.R. *Nature*—MacMillan & Co. Ltd., St. Martin St., London WC 2, Vol. 158, No. 4009, p. 285.